Fort Cobb Basin -
Modeling and Land Cover Classification

FINAL REPORT

Submitted to

Oklahoma Conservation Commission

Submitted by

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Acknowledgment

We would like to thank Oklahoma Conservation Commission personnel, specifically Monty Ramming, for providing the ground truth data and crop management information which are critical to developing a good model.

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Introduction

Background and Purpose

The Oklahoma Conservation Commission (OCC) is concerned about water quality issues in the Fort Cobb Reservoir/Cobb Creek Basin. The Fort Cobb Basin is located in Southwestern Oklahoma in Caddo, Washita, and Custer Counties. The basin area is 314 square miles and the surface area of the Fort Cobb reservoir is 4,100 acres. Fort Cobb Reservoir and six stream segments in its basin are listed on the 1998 303(d) list as being impaired by nutrients, pesticides, siltation, suspended solids, and unknown toxicity. In order to mitigate the effects of nonpoint source pollution in the basin, OCC has crafted a large-scale implementation program to address the sources of pollution.

The purpose of the project is to demonstrate the benefits of nonpoint source (NPS) implementation on the water resources of the Fort Cobb Reservoir Basin. The objectives of the project are to promote protection and re-establishment of buffer zones and riparian areas; demonstrate practices necessary to achieve the sediment, nutrient, and pesticide control needed to protect the Cobb Creek and Fort Cobb Reservoir; and implement practices identified by the Watershed Restoration Action Strategy and a TMDL to improve water quality.

The project was separated into two components. Applied Analysis Incorporated was subcontracted by Oklahoma State University to develop a current land cover theme for the basin. The report submitted by Applied Analysis Incorporated to Oklahoma State University is listed in Appendix A. Oklahoma State University performed the modeling portion of the study which is detailed in the bulk of this report.

Modeling Sediment and Nutrient Loading for the Fort Cobb Basin

Two separate modeling components were performed by Oklahoma State University. The first task was estimating erosion from county roads using the Water Erosion Prediction Project (WEPP) Model. The second task was modeling nutrient and sediment loads from upland areas using the Soil and Water Assessment Tool (SWAT) Model.

Erosion Estimates From County Roads

The density of unpaved county roads was estimated using available Geographic Information Systems (GIS) data and ground truth data. The accuracy of these GIS data were greatly improved using detailed ground truth by Oklahoma Conservation Commission personnel. A USGS Digital Elevation Model (DEM) was used to estimate slope and slope length along these roads. The WEPP Roads Model (WEPP: Road, Elliot, William et al., USDA, Forest Service Rocky Mountain Research Station,1999) was applied to estimate average annual erosion.

Nutrient and Sediment Loading Using SWAT

Loading to the reservoir was estimated as well as loading from different portions of the basin using SWAT 2000 (Arnold, Jeff. et al., USDA, Agricultural Research Service. Grassland, Soil, and Water Research Laboratory, 2002). Land cover specific loading was simulated to show the fraction of the total load to the reservoir originating from each land cover type. Areas that contribute a disproportionate amount of sediment were identified to target OCC water quality programs.

County Roads Erosion Estimates

County roads in the Fort Cobb Basin were considered a potentially significant contributor of sediment to the reservoir by the OCC. The Water Erosion Prediction Project (WEPP) for roads model was used to estimate road and bar ditch erosion.

Input Data

The WEPP: Road interface is accessible via the internet at http://forest.moscowfsl.wsu.edu/cgi-bin/fswepp/wr/wepproad.pl. The interface requires:

- Climate Station
- Soil Texture
- Road Design
- Road Surface
- Road Gradient
- Flow Length
- Road Width

Climate Data

Climate data collected at a station in Weatherford, Oklahoma were utilized in the analysis. Thirty years of data were simulated for use in WEPP based on statistics collected at the Weatherford station. This process was performed by the online interface.

Soil Texture, Road Surface, and Design

Oklahoma Conservation Commission personnel performed extensive ground truthing of the roads in the basin. Data on road surfaces, soil textures, and bar ditch conditions were collected for each 1/4 mile and attributed onto US Census Bureau Topologically Integrated Geographic Encoding and Referencing System (TIGER) road location data (Table 1). The result is shown in Figure 1. Roads were assumed to be 10 meters wide including both bar ditches.

Road Gradient and Flow Length

Slope was derived from USGS 10 meter DEMs. Individual quads were stitched together to cover the entire basin. These data were integer grids with elevation in meters. Slopes derived from an integer grid in low relief areas are inaccurate. Therefore, these data were converted to a floating point grid by converting the original grid to contour lines, then to a Triangulated Irregular Network (TIN), and finally back to a grid (Figure 1). Converting the grid to contour lines extracts data at locations where integer data were most likely to be accurate. The conversion to a TIN extrapolates the elevations for the areas between the contour lines. The resulting grid was suitable for slope derivations the WEPP Roads model.

Road length was derived from a simplified TIN (using a Z tolerance of 3 meters) and the TIGER road theme attributed with ground truth data. This resulted in a vastly simplified TIN which ignores small undulations in topography. This TIN was used to break the road theme into sections with similar aspects. The road network for the basin was separated into approximately 11,000 segments with each having different properties.

Methods

The only WEPP roads interface available is web based and does not allow batch processing. With 11,000 road segment it is not feasible to run each manually. Therefore, a set of 432 computer simulations covering a variety of conditions were run manually via the web interface. These data were used in conjunction with software written specifically for this task to interpolate sediment yield for each of the 11,000 road segments.

Results

Assuming a 10 m road width, roads cover 1.07% (916 ha) of the basin and contribute 6029 Mg (6,029,000 kg) of sediment annually as predicted by the WEPP Roads model. The sediment contribution of the different road surfaces and bar ditch conditions are shown in Table 1. The fraction of roads in each category and their average length are shown in Tables 3 and 4. At first glance sediment rates for paved roads appear disproportionally high as compared to dirt roads, but the paved roads have longer segment lengths on average for some bar ditch conditions. Paved roads also have virtually no infiltration, thus producing more surface runoff. Bar ditch erosion is very sensitive to segment length and runoff volume.

Table 1 Road ground truth categories reported by Oklahoma Conservation Commission personnel.

Bar Ditch Conditions	Road Surface	Soil Types*
Stable and Vegetated	Paved	Sand
Stable and Rocky	Gravel	deep sand
Starting to Erode	Gravel and Dirt mix	Clay
Actively Eroding	Dirt	Bedrock
Deep Erosion and Cutting		
Flume		

* Soil types reported for dirt roads only.

Table 2 Road and bar ditch erosion by road surface type and bar ditch condition as predicted by the Water Erosion Prediction Project (WEPP) Model.

Average Sediment Yield (Mg/km/yr)				
	Stable	Eroding	Flume	All Ditch Types
Paved	2.1	10.2	0.0	**3.2**
Gravel	7.7	14.9	13.1	**10.0**
Gravel and Paved	6.5	18.0	24.2	**13.8**
Dirt	4.9	9.0	11.5	**7.9**
All Surfaces	**3.6**	**12.8**	**6.2**	**6.6**

Total Annual Sediment Yield (Mg/yr)				
	Stable	Eroding	Flume	All Ditch Types
Paved	898	689	0	1587
Gravel	763	657	11	1430
Gravel and Paved	340	1539	39	1917
Dirt	180	910	4	1095
All Surfaces	**2180**	**3795**	**54**	**6029**

Table 3 Total length of roads in the Fort Cobb Basin by surface type and bar ditch condition.

Total Road Length (km)				
	Stable	**Eroding**	**Flume**	**All Ditch Types**
Paved	423	67	6	496
Gravel	99	44	1	143
Gravel and Paved	52	85	2	139
Dirt	37	101	0	138
All Surfaces	**611**	**297**	**9**	**917**

Table 4 Average length of road segments in the Fort Cobb Basin by surface type and bar ditch condition.

Average Road Segment Length (m)			
	Stable	**Eroding**	**Flume**
Paved	84.3	76.8	93.7
Gravel	85.3	75.7	80.3
Gravel and Paved	80.8	83.9	51.5
Dirt	73.8	77.9	64.6

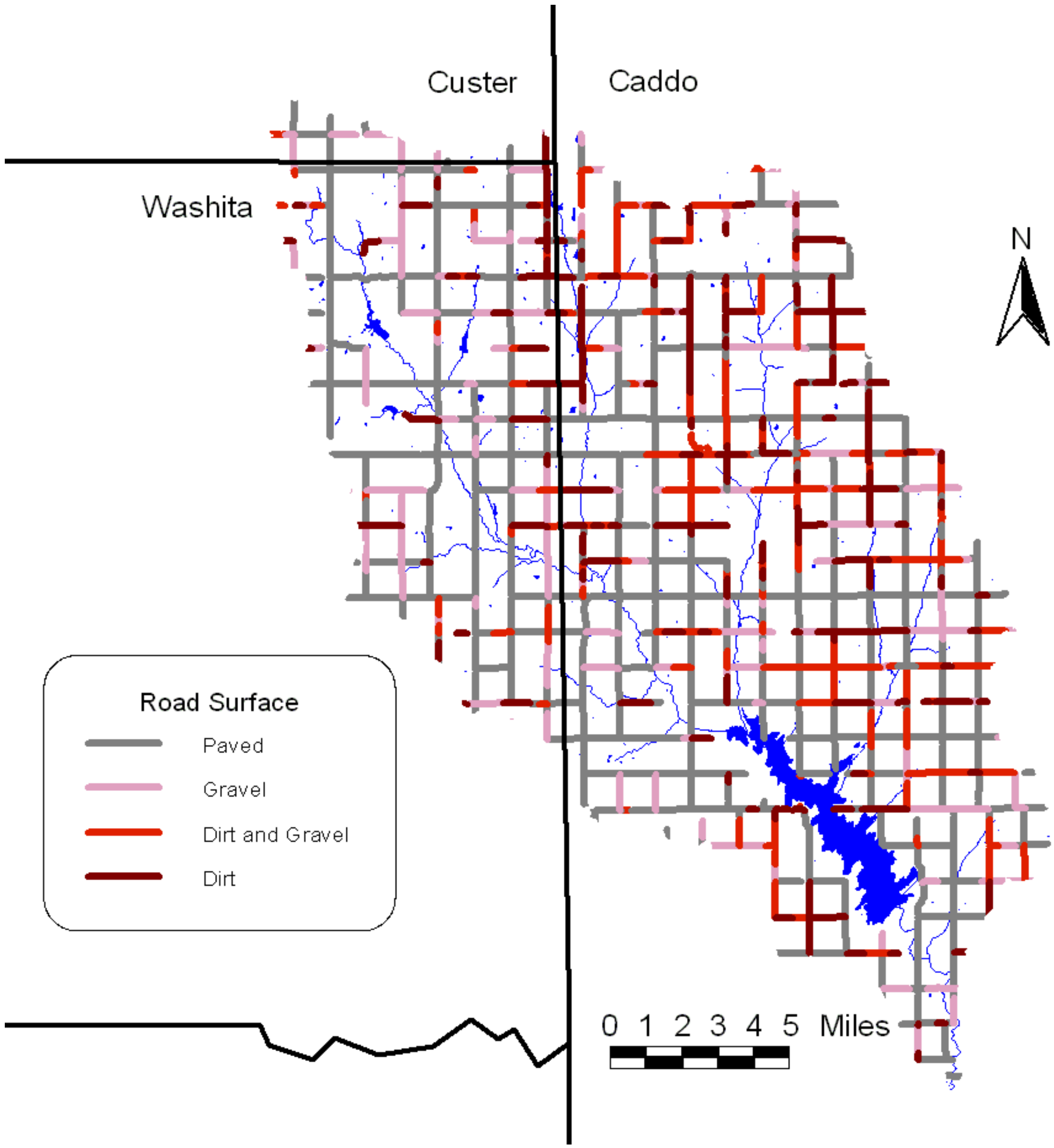

Figure 1 Road surface conditions in the Fort Cobb Basin derived from US Census Bureau Topologically Integrated Geographic Encoding and Referencing system TIGER data and ground truth collected by Oklahoma Conservation Commission personnel.

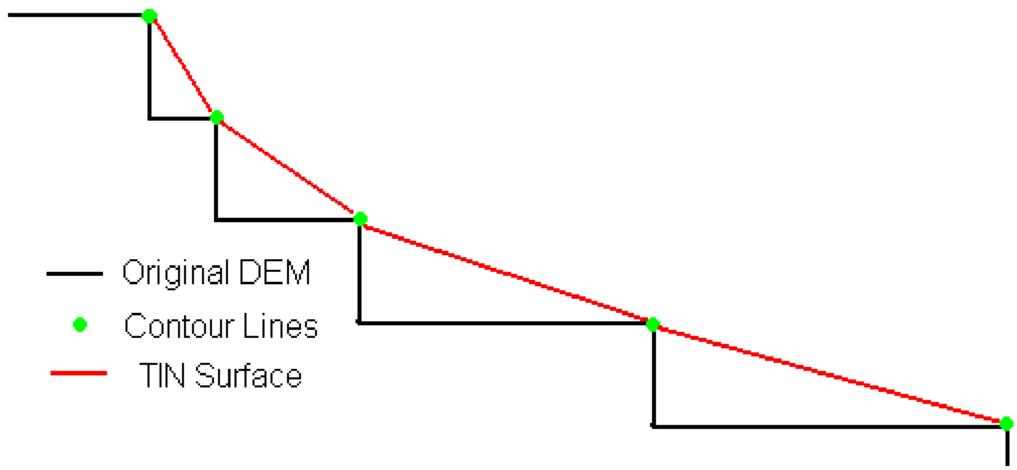

Figure 2 Illustration of how the TIN, the original USGS DEMs, and the contour lines compare.

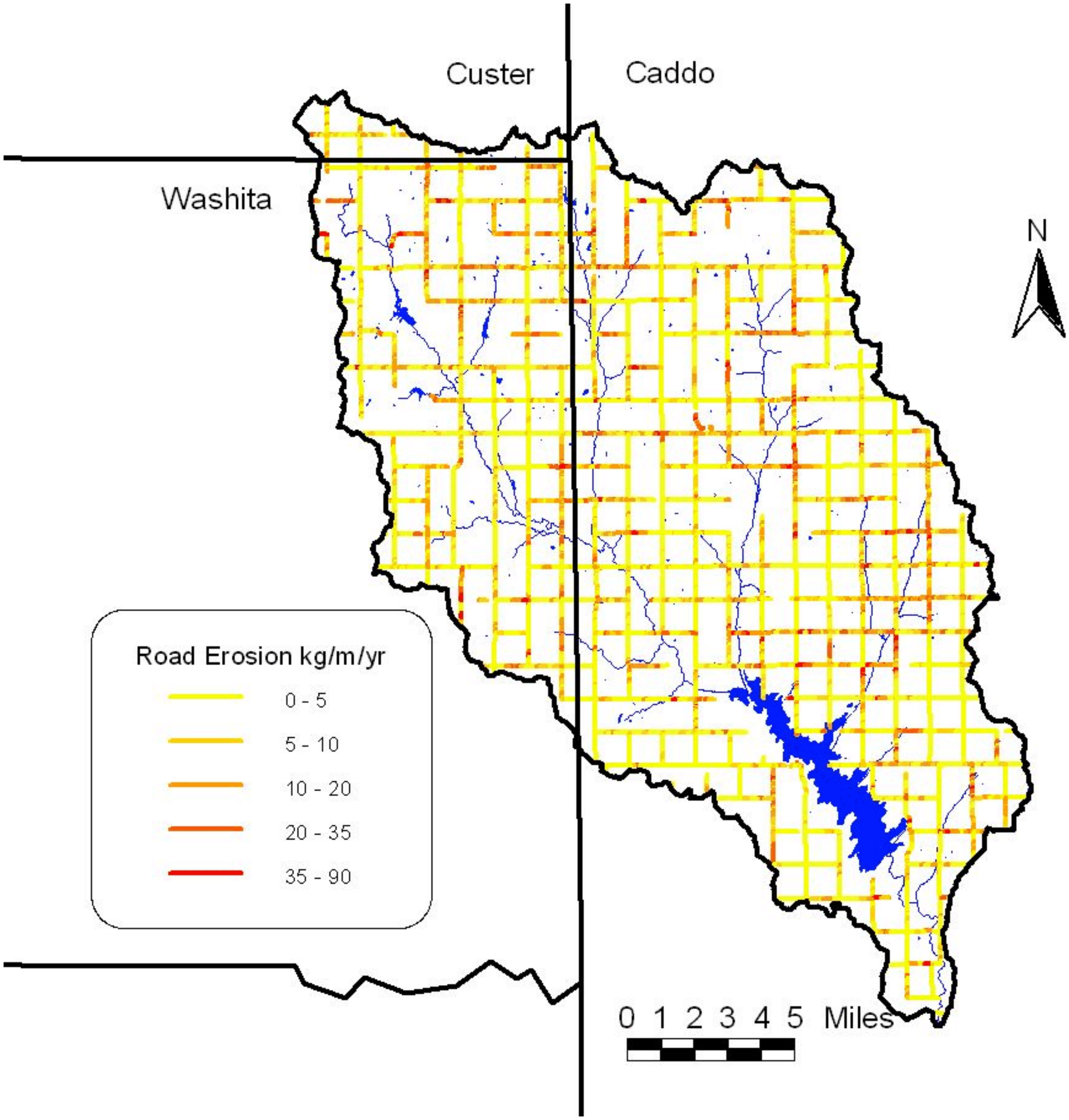

Figure 3 Water Erosion Prediction Project (WEPP) predicted road erosion in the Fort Cobb Basin.

Nutrient and Sediment Loading Using SWAT

The SWAT 2000 model was used to estimate erosion and nutrient loading from the upland areas of the basin. SWAT is a distributed parameter basin scale model developed by the USDA Agricultural Research Service at the Grassland, Soil and Water Research Laboratory in Temple, Texas. SWAT is included in the Environmental Protection Agency's (EPA) latest release of Better Assessment Science Integrating Point and Nonpoint Sources (BASINS).

Input Data

Because SWAT is a distributed model, data requirements are vast and data manipulation is difficult. These requirements are met using a ArcView GIS interface, which generate model inputs from commonly available GIS data. These GIS data are summarized by the interface and converted to a form usable by the model. Below is a list of GIS data that were utilized:

- 10 m USGS DEM (Figure 4)
- 200 m NRCS MIADS Soils Data
- 30 m AAI Land Use Data Layer (Figure 5)
- EPA Reach3 Streams

In addition, tabular weather data from the NOAA Cooperative Observation Network (Surface Data, Daily, NOAA National Climatic Data Center, 2003) were used in all modeling. The hydrologic portion the model was calibrated using USGS stream gage data and the observed weather data.

Land cover data from AAI were combined with a crop type breakdown based on 1999-2001 Oklahoma Agricultural Statistics Service data (Table 5) (http://www.nass.usda.gov/ok/, USDA, 2002) and center pivot irrigation locations tagged from aerial photography (Figure 6) (ftp://okmaps.onenet.net, Digital Orthographic Photography, dates vary). These data allowed us to separate the Agricultural category from AAI into four separate crops categories (Figure 7).

Land cover specific data, such as soil test phosphorus and current fertilization practices, are not widely available. Soil test P for common agricultural land covers were derived from OSU county level averages for the period 1995 -1999. Current fertilization and management practices are based on OSU recommendations and knowledge of local OSU Extension and Conservation District personnel (primarily Monty Ramming) (Table 6). Table 6 includes SWAT predicted sediment yields based on model runs of each management scenario on a single HRU, with a Woodward soil and a slope of 3.6%. Single cropped peanuts and sorghum are included in Table 6 but were not used in the model.

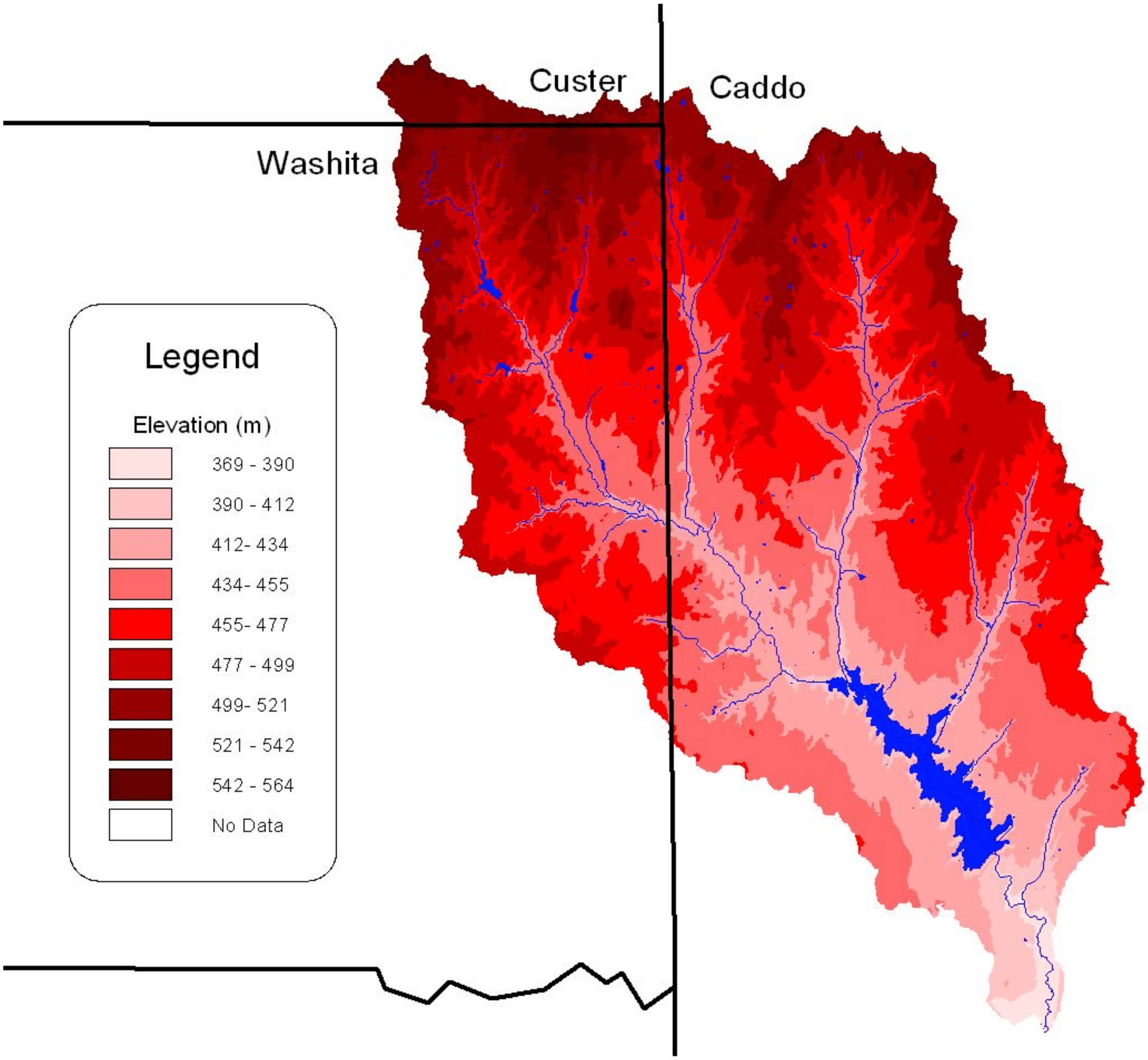

Figure 4 Ten meter USGS Digital Elevation Model (DEM) with county boundaries for the Fort Cobb Basin.

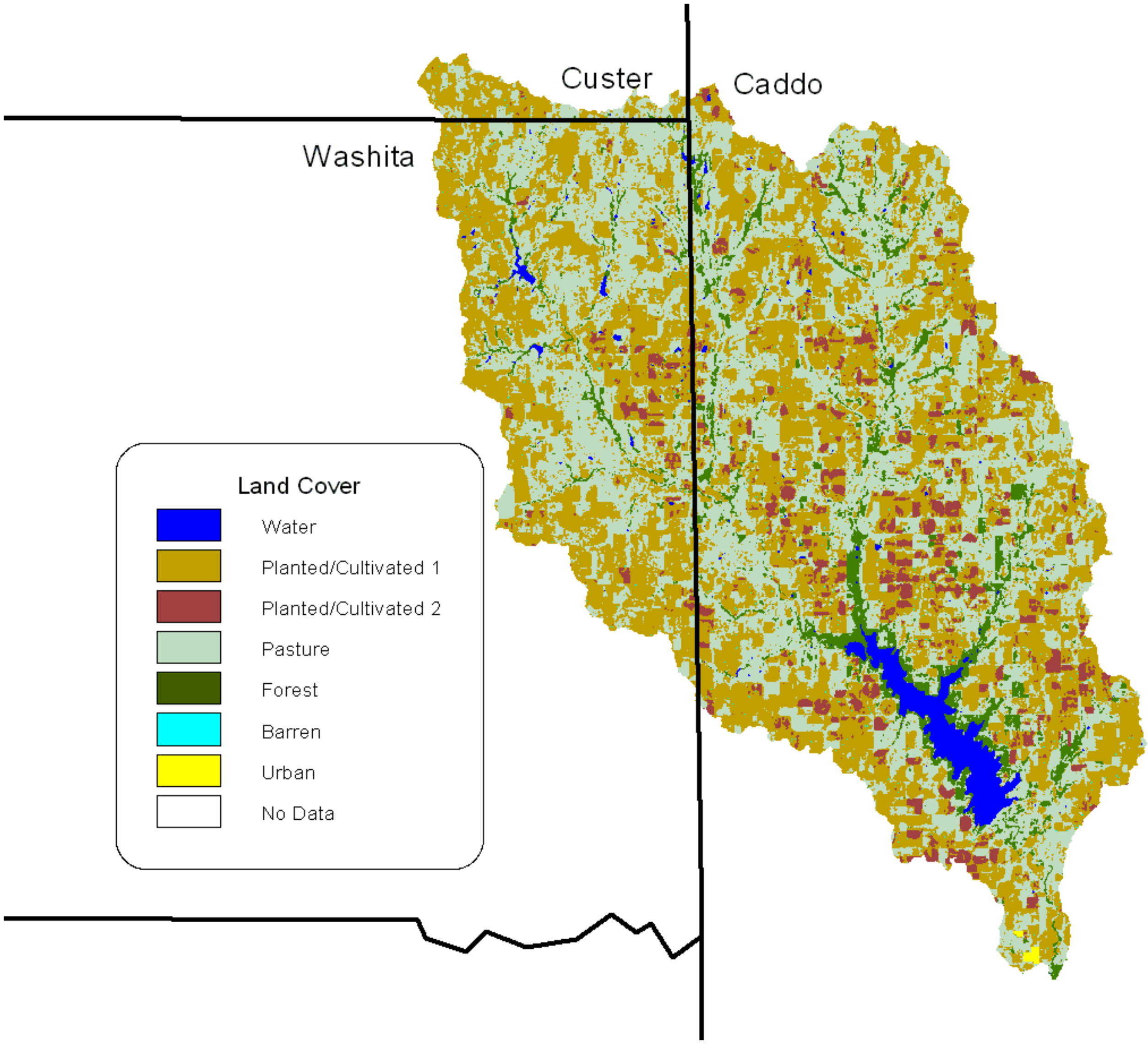

Figure 5 Thirty meter Applied Analysis Incorporated Landsat derived land cover with county boundaries for the Fort Cobb Basin.

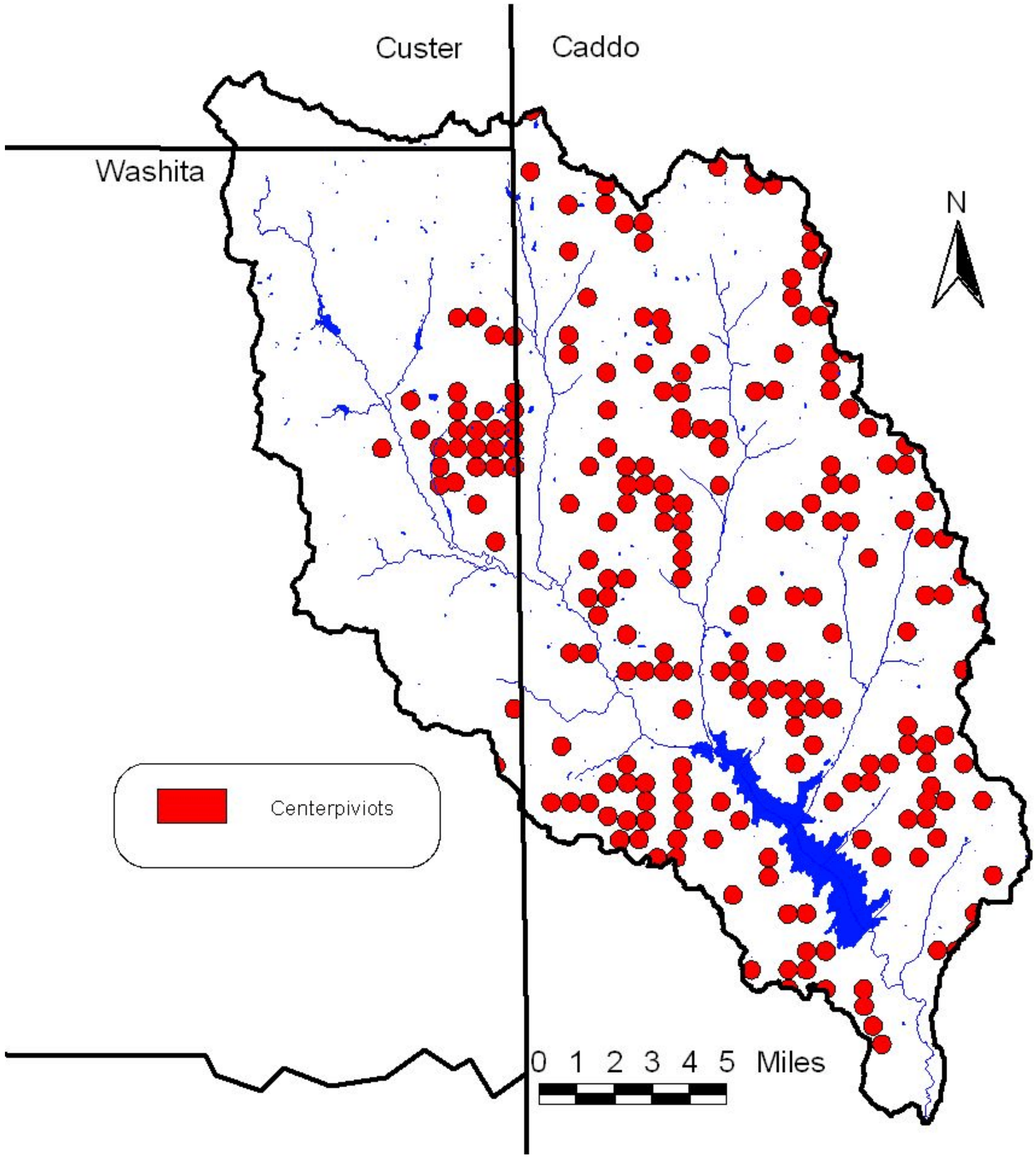

Figure 6 Center pivot irrigation systems tagged from 1 m digital aerial photography for the Fort Cobb Basin.

Table 5 Crop breakdown based on 1999-2001 National Agricultural Statistics Service data**.**

Irrigated Cropland	Peanuts	71%
	Sorguhm	29%
Non-Irrigated Cropland	Wheat for Grain	76%
	Wheat for Pasture	24%

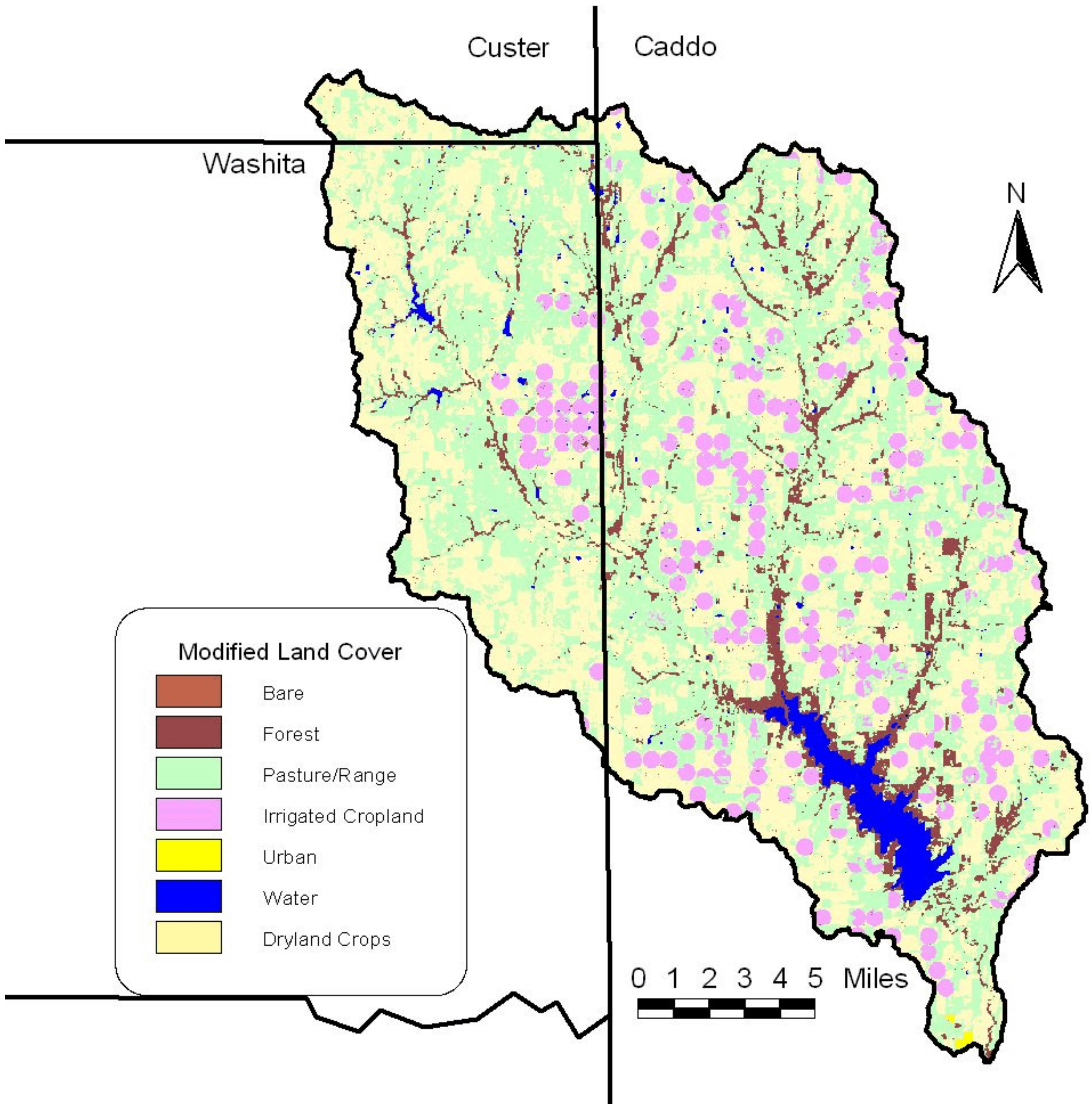

Figure 7 Land cover coverage incorporating Applied Analysis Incorporated land cover data, center pivot locations, and National Agricultural Statistics Service data.

Table 6 Management operations SWAT predicted sediment yields on a single Hydraulic Response Unit with identical properties other than management. Soil and subbasin properties are listed in the lower right section. *Peanut Only* and *Sorghum Only* were not used in the model and are listed for comparison purposes only.

Peanut/Wheat	Wheat for Grain	Wheat Graze out	Sorghum/Wheat
4.9 ton/ha Sediment	**7.0 ton/ha Sediment**	**7.3 ton/ha Sediment**	**7.9 ton/ha Sediment**
Kill Wheat April 15	Harvest Wheat June 1	Kill Wheat May 1	Harvest Wheat May 25
Fertilize 27 lb/acre N April 16	Fertilize 120 lb/acre N Sept 20	Fertilize 70 lb/acre N Aug 20	Fertilize 40 lb/acre N May 27
Fertilize 70 lb/acre P2O5 April 16	Fertilize 30 lb/acre P2O5 Sept 20	Fertilize 30 lb/acre P2O5 Aug 20	Fertilize 15lb/acre P2O5 May 27
Disk April 17	Disk Sept 22	Disk Aug 22	Disk May 28
Disk April 17	Disk Sept 22	Disk Aug 22	Disk May 28
Insecticide Temik 1 lb/acre ai April 17	Springtooth Sept 24	Springtooth Aug 24	Insecticide Temik 1 lb/acre ai May 28
Herbicide Lasso 3 lb/acre ai April 17	Plant Wheat Sept 25	Plant Wheat Aug 25	Herbicide Lasso 2.5 lb ai/acre May 28
Springtooth April 18	Grazing 1/3 au/acre for 90 days Dec 1	Grazing 1/3 au/acre for 150 days Nov 15	Springtooth May 29
Plant Peanuts April 19			Plant sorghum June 1
Auto irrigation April 20			Auto irrigate June 20
Harvest Peanuts Oct 15			Harvest sorghum Oct 15
Fertilize 40 lb/acre N Oct 17			Fertilize 82 lb/acre N Oct 17
Fertilize 15 lb/acre P2O5 Oct 17			Disk Oct 18
Disk Oct 18			Disk Oct 18
Disk Oct 18			Springtooth Oct 19
Springtooth Oct 19			Plant Wheat Oct 20
Plant Wheat Oct 20			
Grazing 1/3 au/acre for 130 days Dec 1			

Peanut Only	Sorghum Only
11.9 ton/ha Sediment	**17.5 ton/ha Sediment**
Fertilize 27 lb/acre N April 16	Fertilize 40 lb/acre N May 27
Fertilize 70 lb/acre P2O5 April 16	Fertilize 15lb/acre P2O5 May 27
Disk April 17	Disk May 28
Disk April 17	Disk May 28
Insecticide Temik 1 lb/acre ai April 17	Insecticide Temik 1 lb/acre ai May 28
Herbicide Lasso 3 lb/acre ai April 17	Herbicide Lasso 2.5 lb ai/acre May 28
Springtooth April 18	Springtooth May 29
Plant Peanuts April 19	Plant sorghum June 1
Auto irrigation April 20	Auto irrigate June 20
Harvest Peanuts Oct 15	Harvest sorghum Oct 15
Disk Oct 18	Disk Oct 18
Disk Oct 18	Disk Oct 18
Springtooth Oct 19	Springtooth Oct 19

Parameter	Value
Soil	Woodward
USLEK	0.37
Hydrologic Soil Group	B
Slope	3.60%
Slope Length	300 ft

Calibration

Few stream gage data were available to calibrate the Fort Cobb Basin SWAT Model for the period Jan 1990 - Oct 2001. The only suitable gage was Cobb Creek Near Eakley (USGS 07325800). The hydrologic calibration was performed predominantly with data from this gage. Another gage down stream of the Fort Cobb Reservoir was also utilized as a check of the calibration (Figure 8). Calibration parameters for ungaged areas were identical to the gaged area on Cobb Creek. Older USGS stream gage data indicated that runoff volume per unit area was similar in other parts of the basin (Table 7). Note that Cobb Creek Near Fort Cobb is downstream of the reservoir and is subject to additional water losses (evaporation, seepage etc.) that occur in reservoir, and therefore it is expected to have a much lower flow per unit area.

The results of the calibration are shown in Table 8 and Figures 9 and 10. Average relative errors were less than 2% at Cobb Creek near Eakley. Comparisons at the Fort Cobb near Fort Cobb gage, which is downstream the reservoir and outside the basin, were 1.78 CMS and 1.79 CMS for observed and simulated flow, respectively. Time-series of monthly flows indicated that the model over predicts peak flows and often underestimates flow during low flow conditions (Figure 9). We think this is the result of the ponds upstream of the gage on Cobb Creek. These ponds were not added to the model as reservoirs. Reservoirs have a filtering effect on stream flow, limiting peak flows by impounding water during storms and releasing water during low flow periods. Due to the way reservoirs are added to the SWAT model, it was not possible to add them during calibration. This limitation mainly effects short term stream flow and should not significantly impact long-term averages. Significant changes to the SWAT model were made during calibration. Table 9 contains all parameter modifications made to calibrate the model for both flow and nutrients.

Total phosphorus and total nitrogen were calibrated using water quality data collected throughout the basin. Insufficient data were available at any given location to accurately estimate nutrient loading. The model was calibrated by comparing individual water quality observations at the same location and time in the model as they were actually taken. The vast majority of these samples were taken under base flow conditions; thus their utility is limited. A total of 62 samples of total nitrogen and 60 samples of total phosphorus were used in the calibration. The results of the nutrient calibration are shown in Figures 11 and 12.

Results

The SWAT model was used to estimate the loading to the reservoir and how the loading varies spatially across the basin. Figures 13, 14, and15 illustrate how the load per unit area varies across the basin. Table 11 displays the load by landcover as predicated by SWAT. The total predicted sediment loading to the reservoir is 245,000 metric ton annually (Table 13).

High Resolution Erosion Mapping

Data from the SWAT model was applied to the original high resolution GIS data to create a map of relative sediment yield for the basin (Figure 17). There are several clusters of high relative erosion in the northern half of the basin. SWAT makes predictions for specific combinations of land cover and soils known as Hydrologic Response Units (HRUs). A database of unique soil and land cover combinations were generated from the HRU level data. If two HRUs had the same soil and land cover, an area weighted average was performed. Included in this database were the annual sediment yield and slope. This database was used to estimate erosion for each grid cell in the original GIS data. Sediment yield was adjusted proportionately based on the slope form the grid cell and the average slope in the database for that particular combination. If a particular land cover and soil combination was not an HRU in the model and therefore not in the database, the average for the land cover was used.

Erosion Targeting

The high resolution erosion map was verified in field and appeared to be very accurate, however a few anomalies were found. In the northwestern portion of the basin several hot spots were discovered to be gypsum outcropings that were miss-classified as crop land in the land cover data. These outcrops are common in Cornick soil series. The Cornick series is characterized by its very shallow soil, with only 5-20 inches to gypsum bedrock. This series is rocky and seldom suitable for tillage. Areas listed in the MIADs soils data as *Rough Broken Land* were also considered unsuitable for tillage. When the land cover data listed one of these soils as crop land, it is likely that a miss-classification has occurred. Exposed rock and bare soil are spectrally similar. These areas were tagged as non-typical in the final product (Figure 18). Crop land areas with slopes greater than 15% were also tagged as non-typical. It is unlikely that tillage would be performed in an area so steep. Priority areas were tagged by ranking the grid cell erosion values and using a cutoff based on area (Figure 19). The final product was generated by dividing the basin into four categories:

- **High Priority** is 5% of the basin with the highest predicted erosion.
- **Medium Priority** includes the next highest eroding 5%.
- **Low Priority** covers the remainder.
- **Non-typical** areas are suspected missclassifications in land cover including agricultural fields with slopes greater than 15%, gypsum outcroppings, or rough broken land.

Summary

The WEPP roads model estimated that the annual sediment loading from roads in the Fort Cobb basin to be 6,030 metric tons per year (Table 13). This represents 2.2% of the 280,000 metric tons per year of sediment loading predicted by the SWAT Model for the entire basin. SWAT predicted sediment load to Fort Cobb Reservoir is 245,000 metric tons per year. The difference is due to the small portion of Cobb Creek between the Fort Cobb Reservoir and the Washita River, which is included in the entire basin estimate. SWAT model predictions combined with high resolution GIS data indicate several sediment “hot spots”. These areas contribute sediment loads more that ten times the basin average on a per hectare basis.

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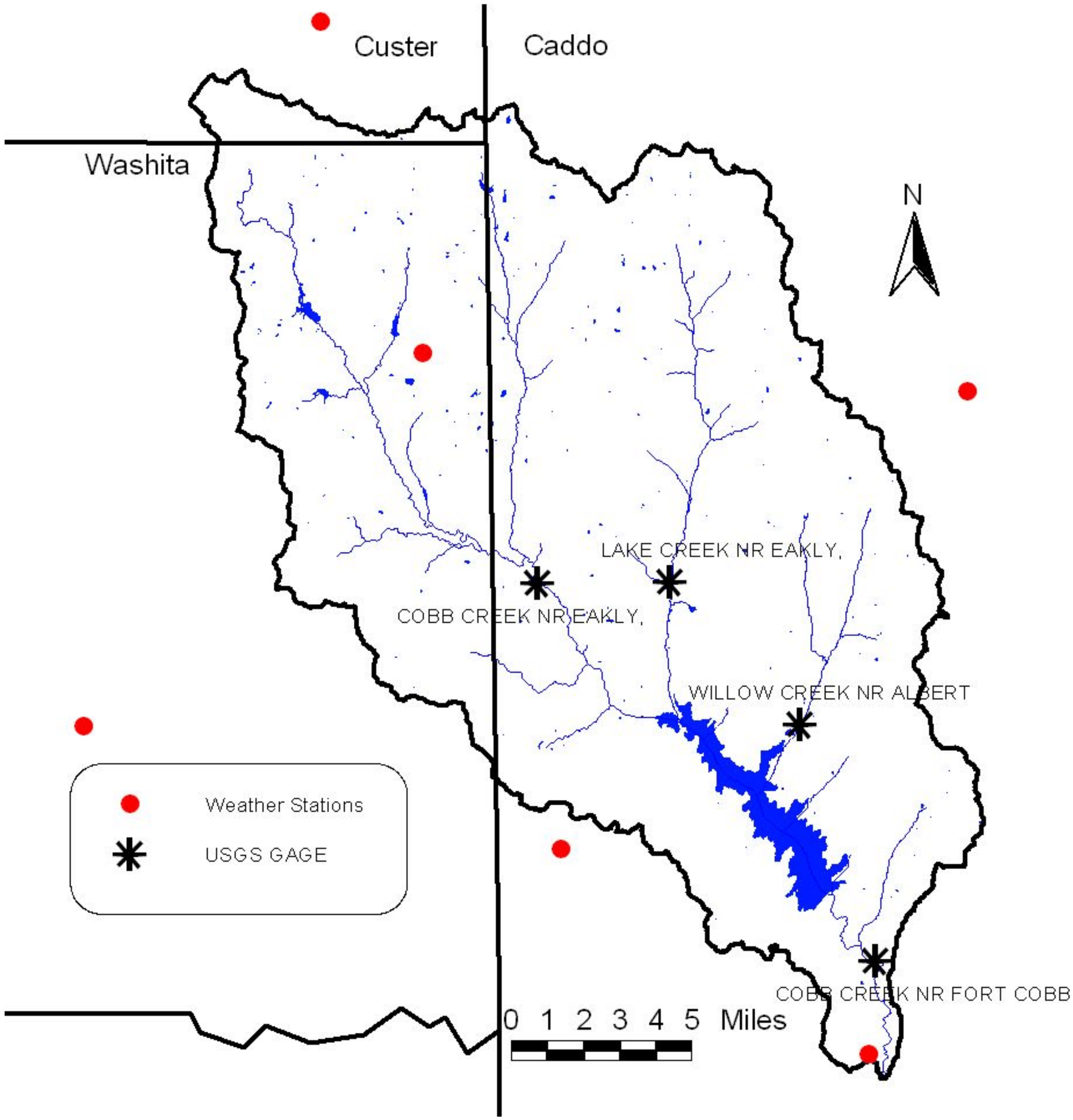

Figure 8 U.S. Geologic Survey (USGS) stream gage and Cooperative Observation Network (COOP) weather station locations in the Fort Cobb Basin.

Table 7 Flow per unit area from 10-1-70 to 6-30-78 for available USGS stations in the Fort Cobb Basin.

Station	Drainage Area (mi^2)	Flow/Area (cfs/mi^2)
Cobb Creek Near Eakley	132	0.18
Lake Creek Near Eakley	52	0.15
Willow Creek Near Albert	28	0.14
Cobb Creek Nr Fort Cobb	307	0.06

Table 8 Average SWAT Model hydrologic calibration results for stream flow at the Cobb Creek near Eakley gage for the period 1/1990-10/2001.

	Total	Surface	Baseflow
Observed	1.09	0.52	0.57
Predicted	1.10	0.53	0.58
Relative Error	-1.6%	-1.7%	-1.5%

Table 9 Parameter values use to calibrate the Fort Cobb SWAT model for both nutrients and flow.

Value	Variable	Description
15	GW_DELAY	Groundwater delay [days]
50	GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur
50	REVAPMN	Threshold depth of water in the shallow aquifer for "revap" to occur [mm]
0.2	RCHRG_DP	Deep aquifer percolation fraction
0.3	ESCO	Soil evaporation compensation factor
0.04	AWC	Soil maximum avalable water content
0.8	USLEP	Universal Soil Losss Equation conservation practive factor
1.5	GW_NO3	Concentration of nitrate in groundwater contribution to streamflow from subbasin
0.2	NPERCO	Nitrogen percolation coefficient
1	PPERCO	Phosphorus percolation coefficient
900	PHOSKD	Phosphorus soil partitioning coefficient
0.55	PSP	Phosphorus sorption coefficient
0.3	RES_K	Reservoir Permeability

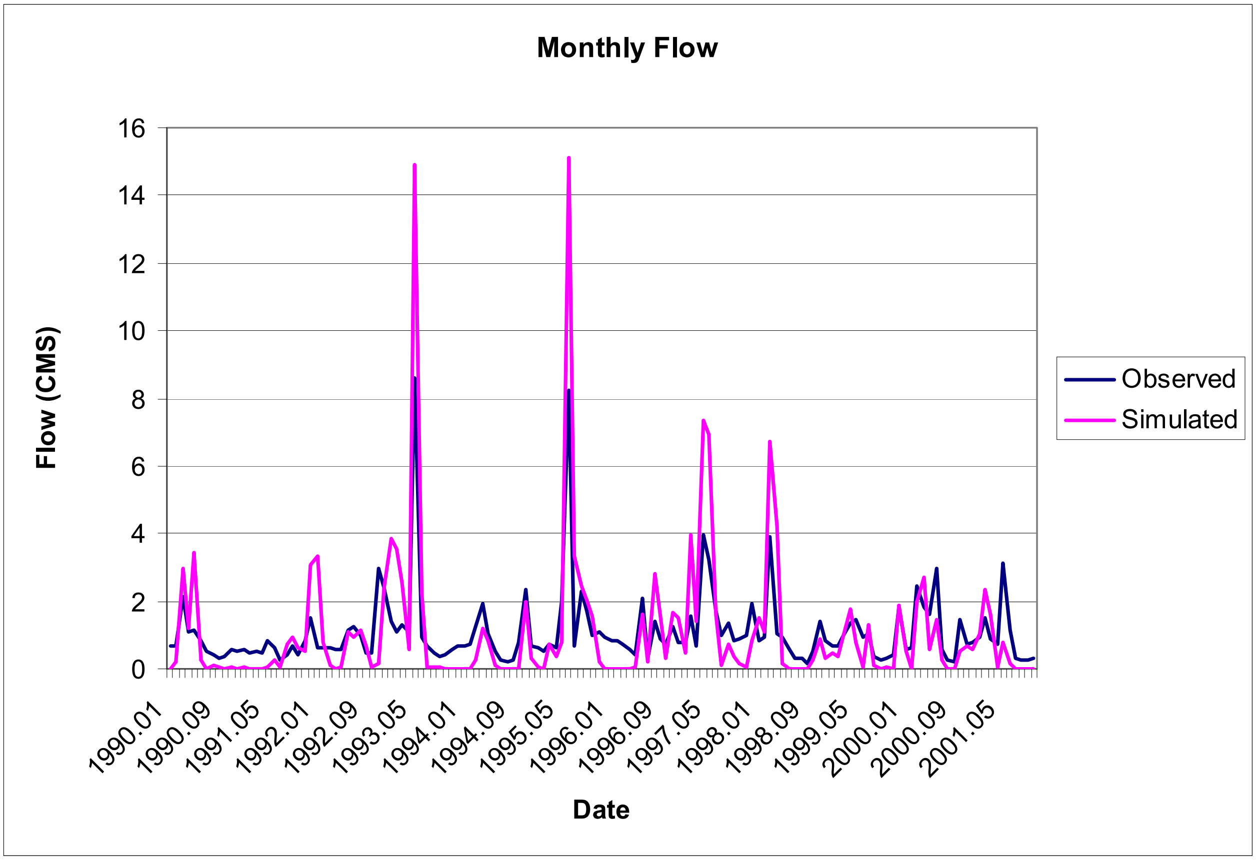

Figure 9 Time-series monthly average observed and SWAT simulated flow at Cobb Creek near Eakley.

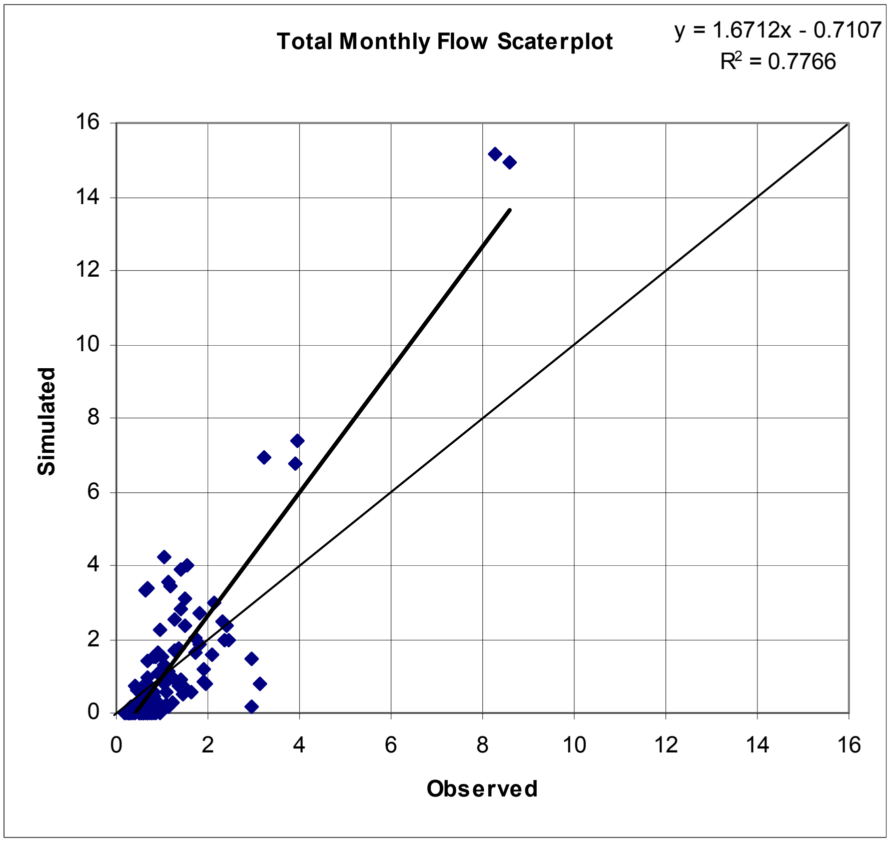

Figure 10 Scatter plot of monthly average observed and SWAT simulated flows at Cobb Creek near Eakley (Flow in CMS).

Table 10 Observed and SWAT model predictions using three different averages.

Type of Average Units	Total P (OBS) (mg/l)	Nitrate (OBS) (mg/l)	Total Nitrogen (OBS) (mg/l)	Total P (SIM) (mg/l)	Nitrate (SIM) (mg/l)	Total Nitrogen (SIM) (mg/l)
Average	**0.17**	**1.03**	**2.22**	**0.13**	**0.93**	**1.39**
Flow Weighted	**1.03**	**0.26**	**1.12**	**1.37**	**0.48**	**5.62**
Flow Weighted With Observed Flow Only	**0.23**	**0.28**	**1.06**	**0.01**	**0.85**	**0.89**

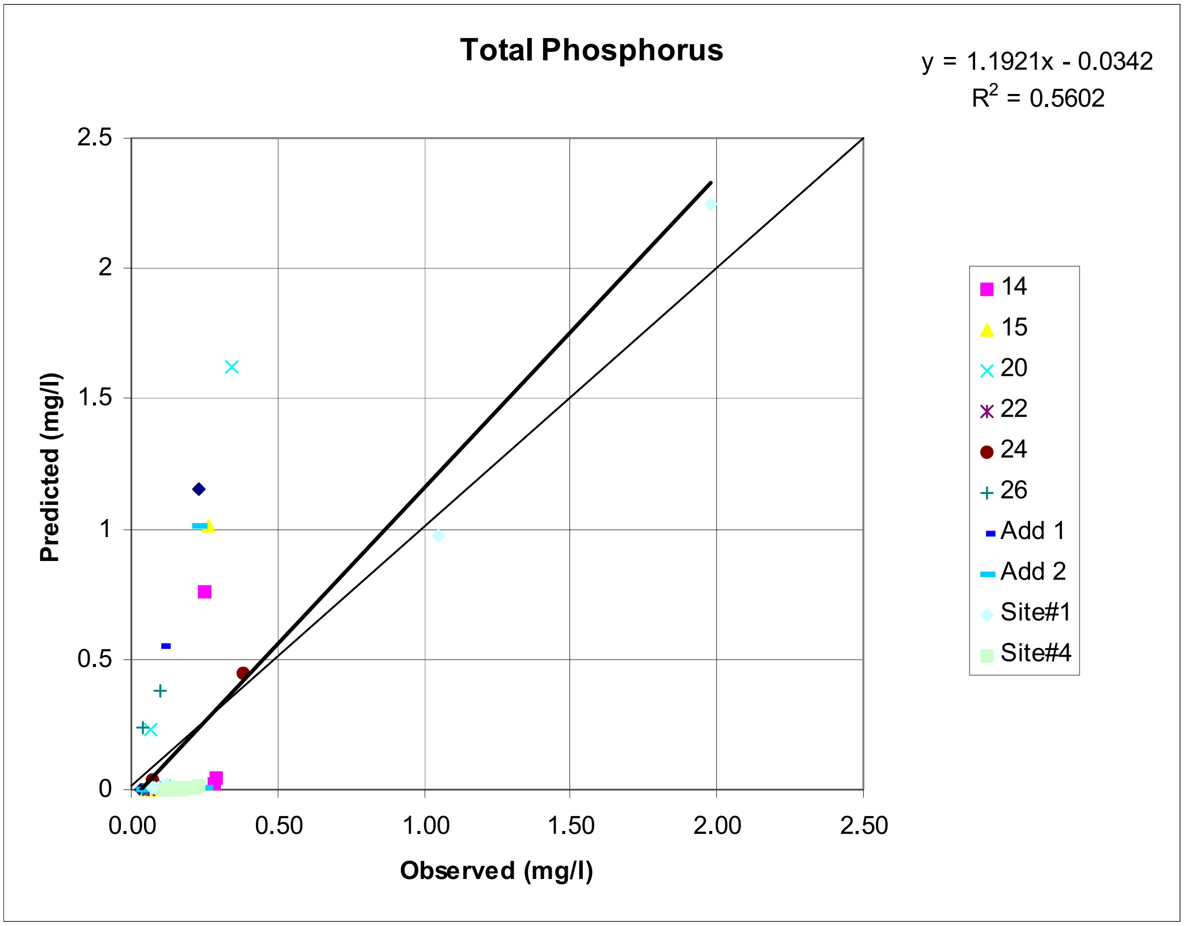

Figure 11 Observed total phosphorus concentrations vs SWAT model predictions for the Fort Cobb Basin. Each series is a different sampling site.

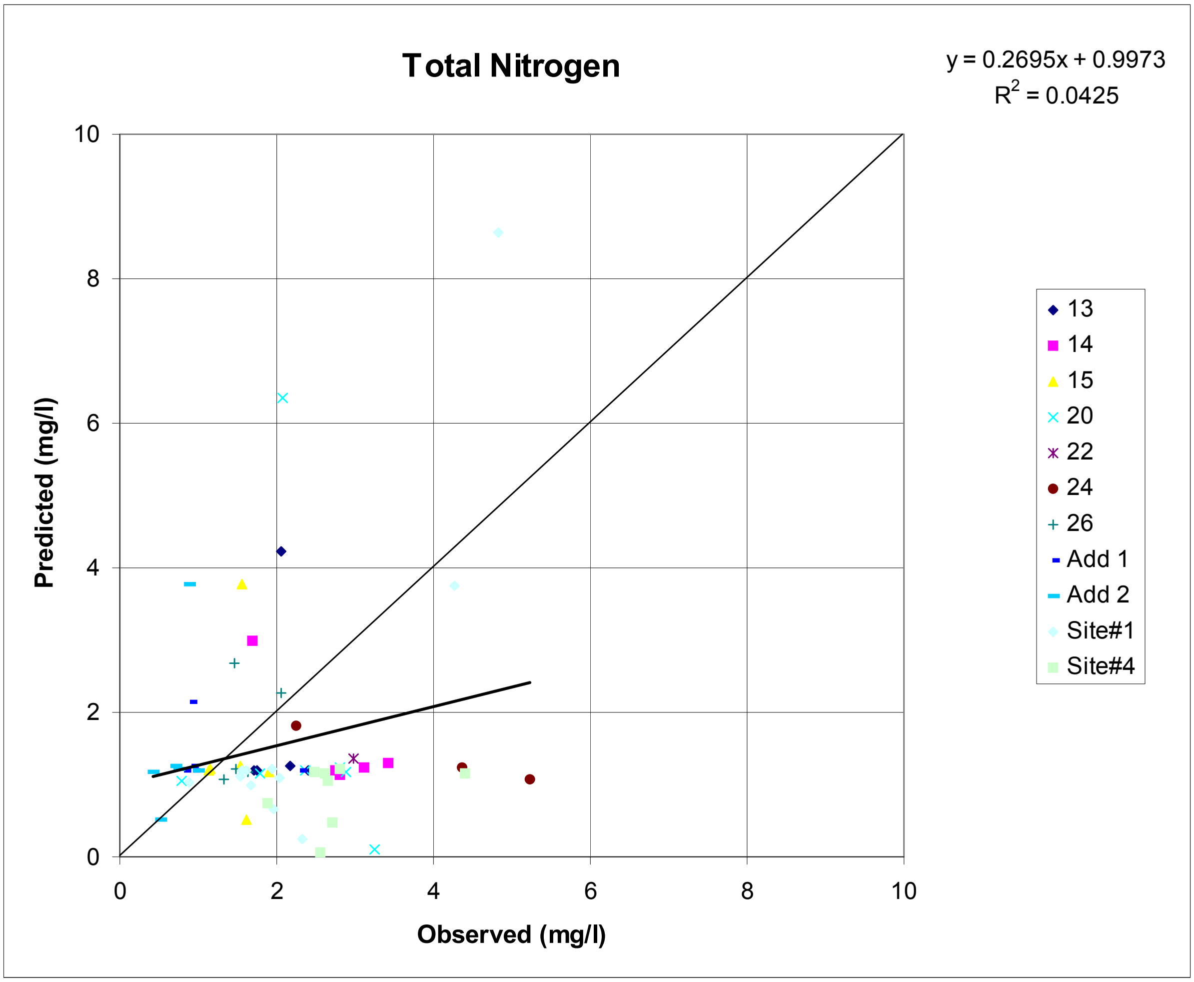

Figure 12 Observed total nitrogen concentrations vs SWAT model predictions for the Fort Cobb Basin. Each series is a different sampling site.

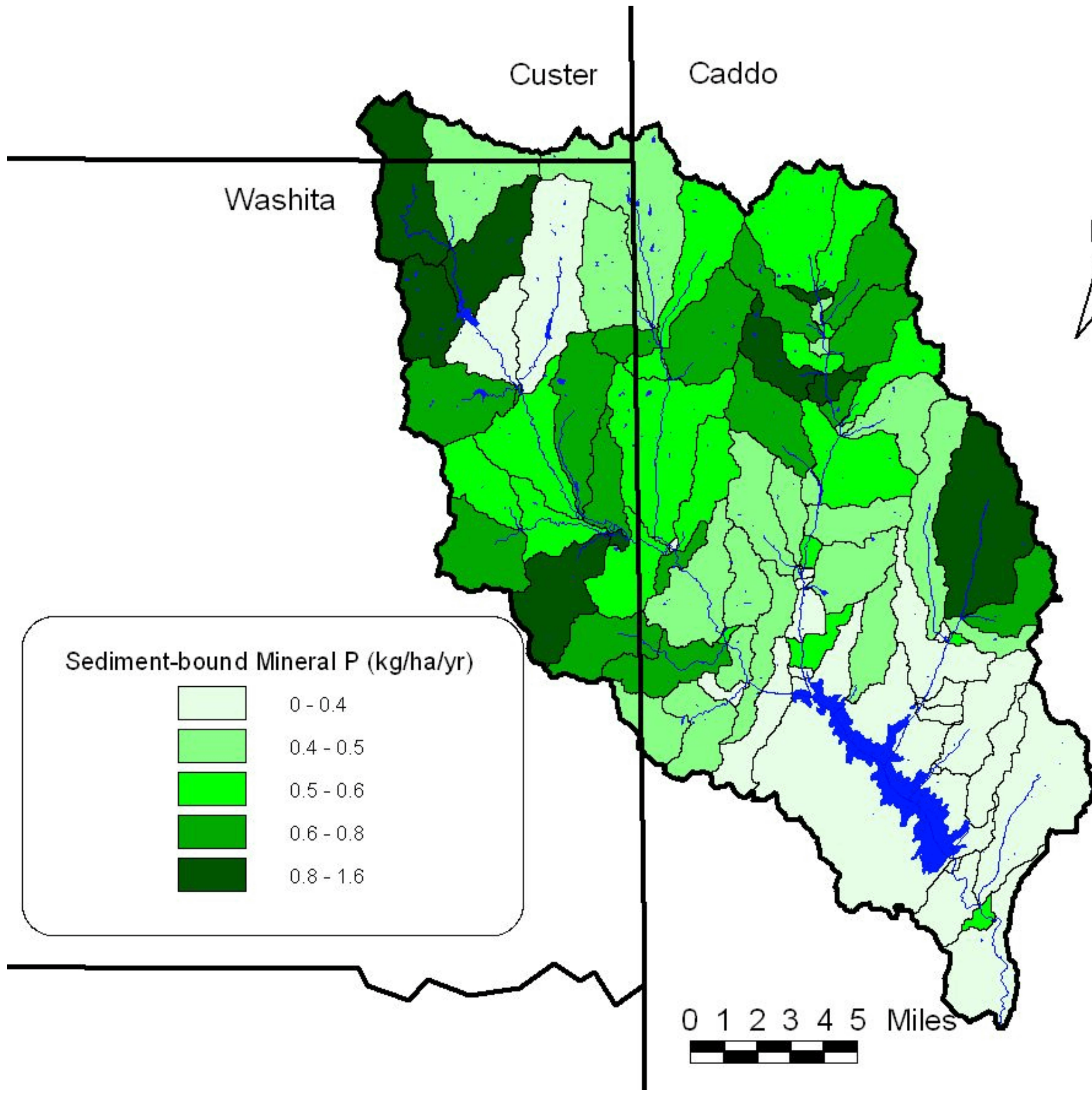

Figure 13 Sediment-bound mineral phosphorus loading across the Fort Cobb Basin as predicated by the Soil and Water Assessment Tool (SWAT) model. Does not include sediment-bound organic forms.

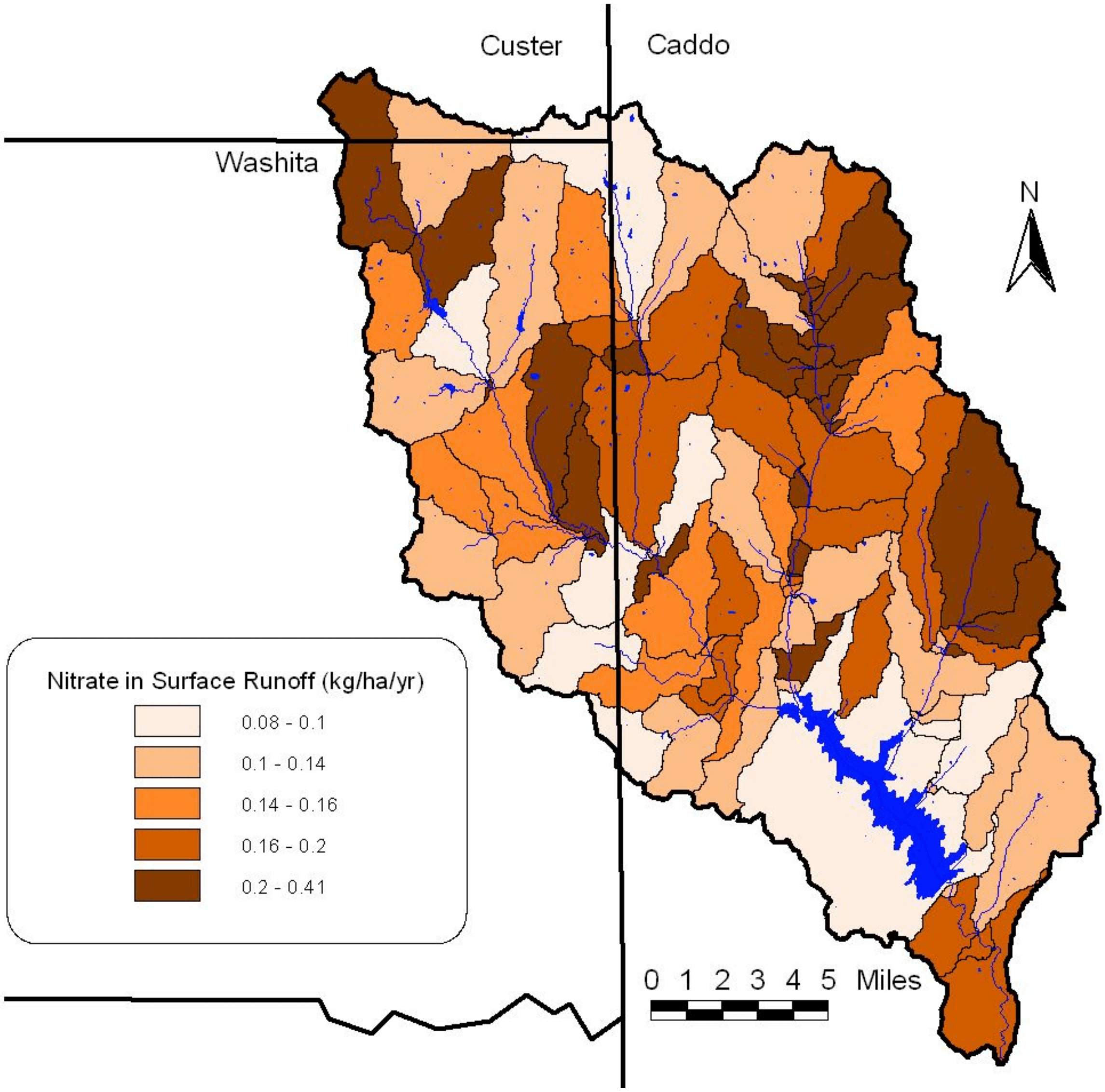

Figure 14 Nitrate in runoff across the Fort Cobb Basin as predicated by the Soil and Water Assessment Tool (SWAT) model.

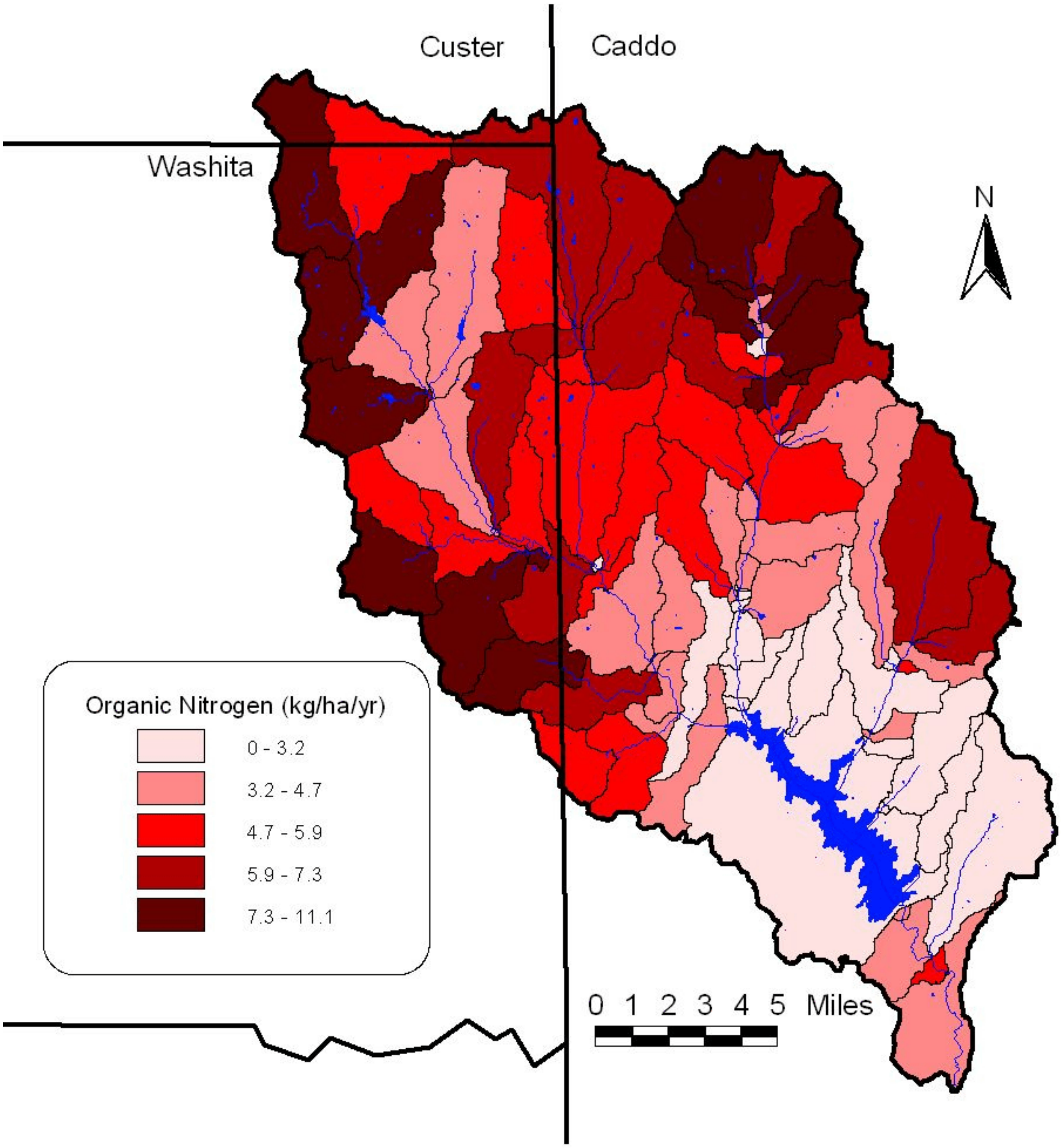

Figure 15 Organic nitrogen yield across the Fort Cobb Basin as predicated by the Soil and Water Assessment Tool (SWAT) model.

Table 11 SWAT simulated loads by land cover for the Fort Cobb Basin for the period 1/1990-10/2001.

Land Cover	Total Phosphorus (kg/ha)	Total Surface Nitrogen (kg/ha)	Total Surface Nitrogen (mg/l)	Total P (mg/l)	Soluble P (mg/l)	Surface NO3 (mg/l)	Sediment Yield (mt/ha)
Forest	0.01	2.12	1.18	0.00	0.00	0.20	0.01
Pasture/Range	0.54	3.16	3.00	0.51	0.01	0.27	1.29
Peanut	1.94	7.87	5.35	1.32	0.02	0.30	4.00
Sorghum	1.54	8.23	5.10	0.95	0.01	0.37	4.17
Urban	0.08	1.13	1.12	0.08	0.02	0.72	0.04
Water							
Wheat for Grain	2.12	10.62	8.73	1.74	0.02	0.38	6.38
Wheat for Other	1.99	9.29	7.82	1.67	0.02	0.29	5.57
Average	1.25	6.40	5.40	1.05	0.01	0.32	3.44

Table 12 Swat predict loads to the Fort Cobb Reservoir by tributary for the period 1/1990-10/2001.
Tributary locations are shown in Figure 17.

Area	Area (km^2)	Flow (cms)	Sediment (mt/yr)	Organic N (kg/yr)	Organic/Sediment-bound P (kg/yr)	Nitrate (kg/yr)	Soluble P (kg/yr)
83	430	1.42	128300	260800	56230	39580	3780
84	173	0.72	66190	103700	22510	20850	1614
85	9	0.06	1931	2091	619	2153	80
86	78	0.39	30230	40780	9401	12430	725
87	13	0.07	1561	2338	542.9	2733	45
88	8	0.04	1485	2066	493	1583	44
89	87	0.31	15031	242034	5746	661	26
Reservoir	**799**	**3.00**	**244728**	**653809**	**95542**	**79990**	**6314**

Table 13 Load summary for the Fort Cobb/Cobb creek Basin as predicted by the SWAT Model for the period 1/1990-10/2001.

Constituents	Total P	Total N	Sediment	Total Surface Nitrogen*
Units	(kg/yr)	(kg/yr)	(Mg/yr)	(kg/yr)
Fort Cobb Reservoir Load	102,000	734,000	245,000	N/A
Cobb Creek Basin Load	106,000	N/A	293,000	546,000

*Does not include nitrogen contributions from sub-surface flows.

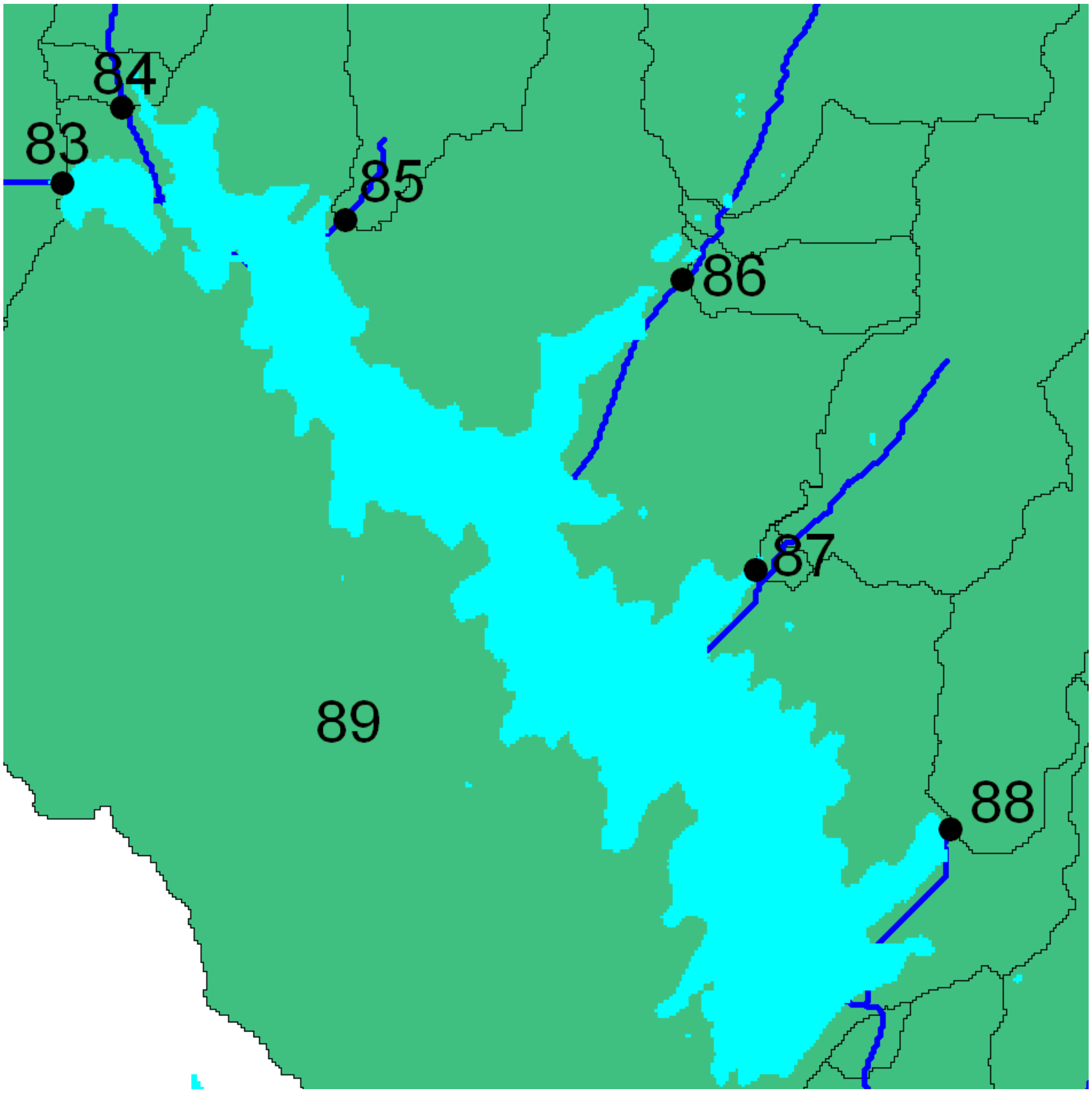

Figure 16 Tributaries flowing into the Fort Cobb Reservoir. Area 89 is the area adjacent to the reservoir.

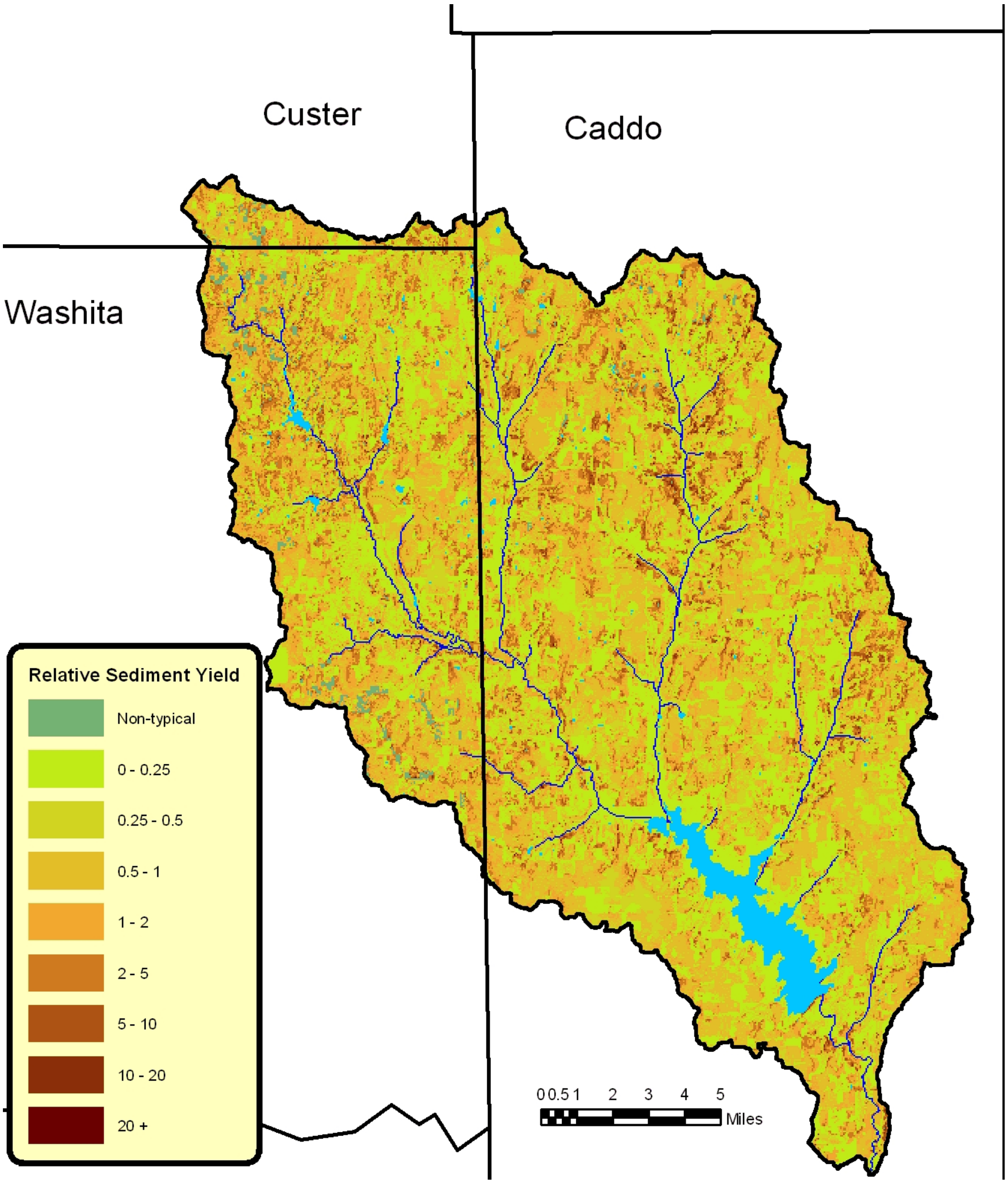

Figure 17 High resolution relative erosion in the Fort Cobb Basin. Based on SWAT model simulations.

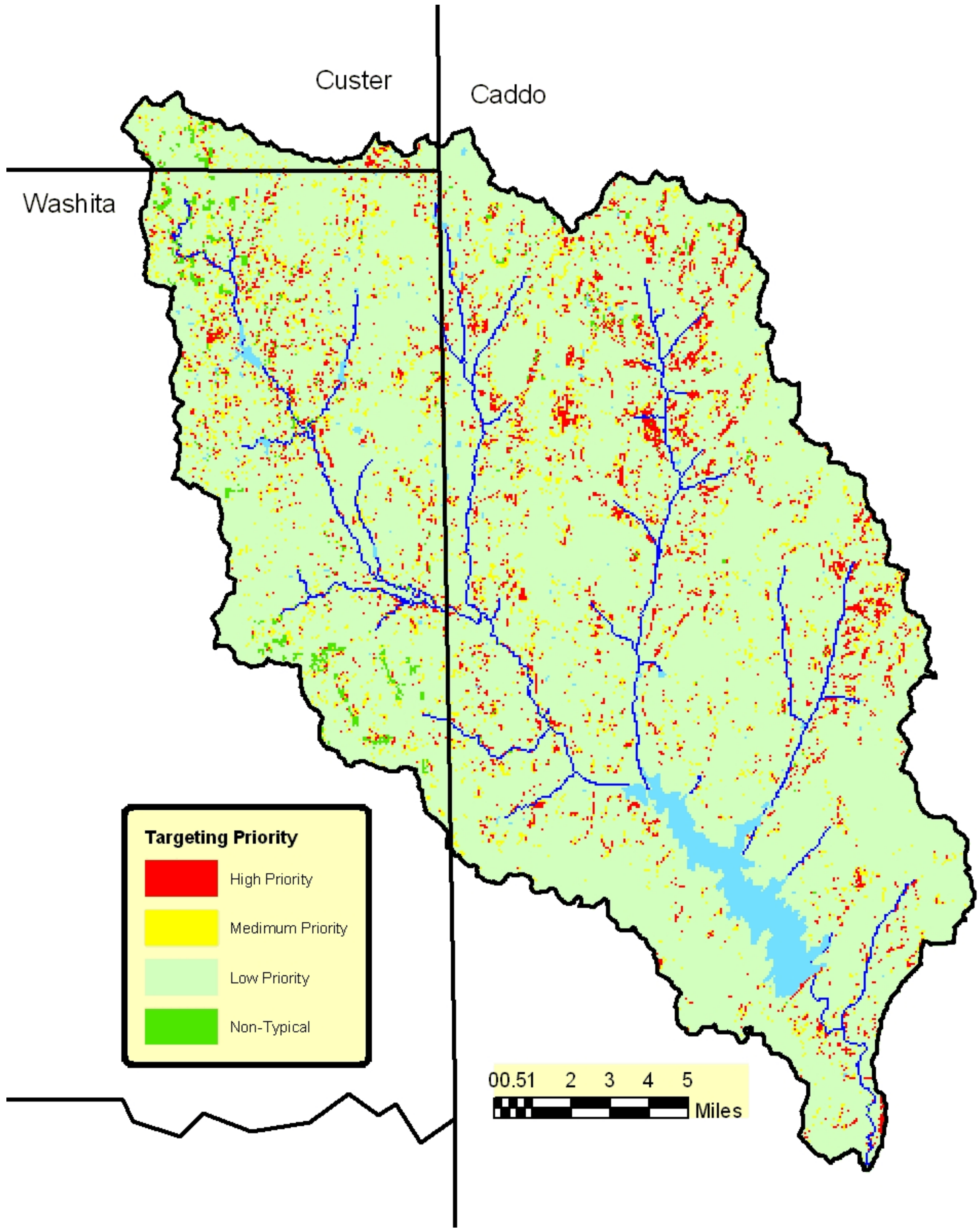

Figure 18 Erosion Targeting Map. High Priority is 5% of the basin with the highest predicted erosion. Medium Priority includes the next highest eroding 5%. Low Priority covers the remainder. Non-typical areas are suspected miss-classifications in land cover including agricultural fields with slopes greater than 15%, gypsum outcroppings, or rough broken land. Derived from Soil and Water Assessment Tool 2000.

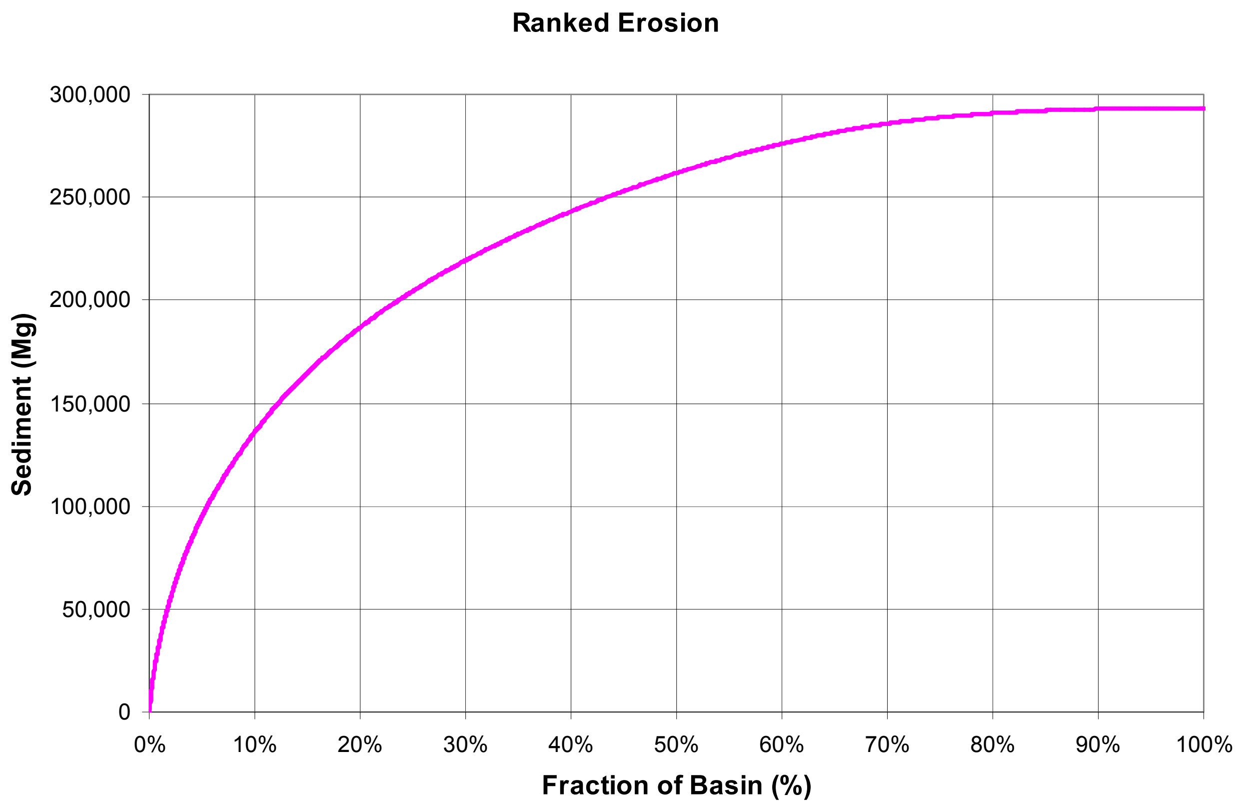

Figure 19 Cumulative ranked grid cell erosion for the Cobb Creek Basin. Based on Soil and Water Assessment Tool predictions.

Appendix A - AAI Land Cover Classification Report

Development of Current Digital Landcover Data Using 30 m TM (Landsat 7 ETM+) Imagery for the Fort Cobb Basin

Prepared for

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by

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01821

September 12, 2002

Fort Cobb Basin Project

Introduction

The purpose of this project was to develop a digital landcover data layer using recent (June 10, 2001) 30 m resolution Landsat TM imagery for the Fort Cobb Basin. Satellite imagery has been used since the 1970's as an accurate and cost effective tool for deriving vegetation and landcover information. Digital processing techniques involving the statistical analysis of image data representing various portions of the electromagnetic spectrum allows for definition of areas that reflect solar radiation in a similar manner. These areas may then be related to landcover or vegetation types through the use of ground truth information.

For this project, a traditional classification method was used where pixels are selected that represent patterns or landcover features that can be recognized or identified with help from other sources, such as ground data, aerial sources (photography, orthophoto quads) or maps. Knowledge of the types of information desired in the end product is required prior to the onset of classification. By identifying patterns, the software is trained to identify pixels with similar characteristics. Applied Analysis Inc. (AAI) relied on local sources to assist in collection of georeferenced ground truth data to ensure the accuracy of the final product. This type of landcover data can be used to conduct watershed assessments, resource inventories, and to detect change in ecosystems.

Ground Truth

Ground truth data and information was provided to Applied Analysis, Inc by Monty Ramming, Oklahoma Conservation Commission (OCC) and Dr. Daniel Storm, Oklahoma State University (OSU). The ground truth data included 1 meter resolution Digital Orthophoto Quarter Quads (DOQQ) from 1995 for the entire Fort Cobb Basin. This data is low altitude panchromatic photography and was registered to the June 10, 2001 Landsat 7 ETM+ scene. Additional ground truth information included a detailed ground survey of two 16 square mile quads located within the watershed. These quads were selected because they contained a representative sample of all the cover types of interest in the watershed and exhibited a high level of spectral variability in the Landsat image. AAI provided OCC copies of the DOQQ's for these quad areas. OCC conducted an extensive ground survey to locate and map large contiguous areas of each cover type. Additionally, OCC provided photographs of select fields of each cover type. These photos along with the field survey were the basis for labeling the spectral classes into the appropriate land cover categories.

Methods

This project mapped landcover types across the Fort Cobb Basin and used a whole pixel classification technique. In this study, we used an unsupervised iterative self-organizing data analysis (ISODATA) clustering algorithm. ISODATA is a widely used clustering algorithm that makes a large number of passes through an image using a minimum spectral distance routine to form clusters. It begins with an arbitrary cluster mean and each time the clustering repeats, the means of these clusters are shifted. The new cluster means are used for the next iteration. This iteration process continues until statistically distinct features emerge.

The methods used to generate the final cover type map across Fort Cobb Basin included a multi-step ISODATA analysis technique. Because of the complex nature of the landcover types across the watershed and the spectral similarity between these landcover categories, four iterations of ISODATA clustering were required to accurately map landcover types. Each iteration of classification generated 100 spectral classes. Spectral convergence threshold was set to 95 percent. The initial classification produced 100 classes which were displayed on top of the Landsat image and DOQQ's as a thematic layer. By visual interpretation of the Landsat imagery and DOQQ's, a set of spectral classes was identified as containing the majority of the forest cover types. The thematic layer was then recoded such that all identified forest classes were recoded to "0" and all other classes were recoded to "1". This layer was saved as a separate file and used as a mask. The mask was applied to the original Landsat image and all pixels that fell within the forest classes were removed. The output masked image was the original Landsat image with all forest pixels removed. This image was then used as the input for the second ISODATA clustering.

The second classification iteration generated 100 spectral classes using the same number of iterations and convergence threshold. This classification was used to extract water from the Landsat imagery. The classification results were again displayed on the Landsat and DOQQ imagery. A set of spectral classes was identified for the category. The set of spectral classes were recoded and saved as a separate file. This file was used as a mask to remove water features from the original image. The output image was the original Landsat image with all forest and water pixels removed. This image (containing mainly pasture and cropland fields) was used as the input for the third classification.

The third classification iteration produced 100 spectral classes. This classification was used to identify and map pasture and planted/cultivated types across the Fort Cobb Basin. The cover type categories included pasture, planted/cultivated 1, planted/cultivated 2 and barren areas. There is tremendous temporal change within and between these cover types. For example, a typical field in the Fort Cobb Basin can be rotated amongst a wide variety of cultivated crops and pasture types. Because of this temporal change and lack of temporal coincidence between the imagery acquisition and ground truth data collection, the ground truth data could not be relied upon solely to guide the selection of spectral classes for the pasture and cultivated categories. A set of decision criteria was established to guide the labeling of spectral classes into landcover categories. The decision criteria are as follows:

1. *Pasture*
    a. Fields with a high to moderate vegetative biomass state;
    b. These fields were relatively homogeneous in their spectral response and in their apparent color in the Landsat imagery;
    c. These fields included cultivated pasture, native pasture and rangeland.

2. *Planted / Cultivated 1*
    a. Fields with a low vegetative biomass state;
    b. These fields were relatively heterogeneous in their apparent color in Landsat imagery;
    c. These fields contained some vegetative spectral response with a significant soil component;
    d. These fields included wheat, peanuts, cotton and other row crops.

3. *Planted / Cultivated 2*
    a. Fields with no vegetative spectral response;
    b. These fields were relatively homogeneous in their apparent color in Landsat imagery;
    c. Fields which have been recently tilled or have such a low vegetative biomass state as to not be spectrally of visually apparent;
    d. Contiguous fields > 1 acre.

4. *Barren*
    a. Fields with no vegetative biomass;
    b. Contiguous fields sized < 1 acre.

These decision criteria were used as a guide for labeling spectral classes into landcover types. The primary means for labeling these spectral classes was the apparent color of the pixels in the Landsat imagery. Each spectral class was analyzed to see what cover types it was detecting. The decision criteria were then used to label that class to an appropriate landcover type.

The third classification was also used to identify any additional forest or water pixels that may have been missed in the two previous classification iterations. Once all the spectral classes were labeled to the appropriate landcover category, the image was recoded such that each landcover category was given a unique identifier.

The June 10, 2001 Landsat imagery showed a significant amount of bare soil fields across the Fort Cobb Basin. The reason for this, according to the Oklahoma Conservation Commission, was that the wheat harvest was underway at that time. Recently harvested wheat fields exhibit an overwhelming soil spectral response in Landsat imagery. Additionally, standing dry wheat fields, due to their lack of chlorophyll, exhibit a similar spectral response as bare soil. Because of the large temporal difference between imagery and ground truth, we were unable to identify which of these spectrally bright fields were standing wheat fields or bare soil. It should be noted that this spectral similarity does not preclude detection of dry wheat fields in Landsat imagery. If temporally coincident ground truth and imagery are acquired, there are several spectral techniques which could be used to detect this crop condition. Because of the previously noted spectral response, many fields in the third classification fell into one or two spectral classes. As a means to further separate landcover categories in these recently tilled or dry fields, a fourth classification iteration was run.

The soil classes were subsetted from the Landsat image. The fourth classification iteration on these high soil areas produced 100 spectral classes. The decision criteria described above were used to separate these spectrally bright fields into the planted/cultivated and barren categories. The set of spectral classes for each category were recoded and saved as separate files.

An additional analysis of *Clump* and *Sieve* was used to separate these bare soil fields between the landcover types of planted/cultivation 2 and barren. *Clump* and *Sieve* are spatial analysis tools to analyze raster data based on class identity and spatial relationship. The fields classified as barren in the fourth classification were run through a clump and sieve routine. All contiguous bare soil fields larger than one acre were reclassified as planted/cultivation 2. All contiguous bare soil fields one acre or less were left in the barren category.

The urban category in the Fort Cobb Basin is underrepresented in this classification because the roads are too narrow to be detected in 30 meter Landsat data. The small town of Fort Cobb was classified as urban by using the roads vector layer to identify the town limits.

The final landcover map for the June 10, 2001 Landsat 7 ETM+ image was produced using standard image overlay techniques. The forest pixels from the first classification, the water pixels from the second classification, the pasture and cultivation types from the third and forth classification, and the clump and sieve and urban layers were added together and recoded to unique identifying numbers. Finally, the classes were color coded and output to a final thematic map.

A riparian habitat assessment was also performed in the Fort Cobb Basin. Hydrologic data layers for the basin were acquired from the USGS via the Oklahoma Digital Atlas. A 100 meter buffer was extended from these hydrologic features to create and assess the spatial distribution of landcover types in the riparian zone. The riparian assessment was unsmoothed, to retain a finer minimum mapping unit and thus increase the spatial utility of each landcover type for best management practice implementation targeting purposes.

Results

With image processing complete, the final results were grouped into 7 landcover classes. The final percentages for landcover in the Fort Cobb basin were calculated and are presented below.

Landcover (by percentage) within the Fort Cobb Basin

Urban – 0.5%
Pasture – 39.72%
Planted / Cultivated 1 – 46.44%
Planted / Cultivated 2 – 5.01%
Forest – 6.68%
Barren – 0.20%
Water – 1.89%

Total – 100%

The basin was dominated by planted/cultivated 1 (46.44%) followed by pasture (39.72%). The other classes exhibited smaller percentages. This was due to the coarse spatial resolution of the Landsat imagery, which allowed some of the narrower roads/urban features and water bodies (streams and creeks) to go undetected or classified with another neighboring landcover type.

In addition to classifying the entire Fort Cobb basin, a detailed riparian zone land cover classification was produced for 100 m buffer around hydrologic features in the watershed. The final results for this riparian zone were quantified and are presented below:

Landcover percentages within the riparian zone of Fort Cobb Basin

Urban – 0.00%

Pasture – 48.47%
Planted / Cultivated 1 – 18.47%
Planted / Cultivated 2 – 0.56%
Forest – 32.42%
Barren – 0.07%

Total – 100%

Discussion

The landcover classification for the watershed and riparian zone maps the spatial distribution of landcover throughout the Fort Cobb Basin. The classification categories planted/cultivated 1, planted/cultivated 2 and barren map the spatial distribution of high soil component fields across the watershed and within the riparian buffer. These classification categories are ranked in order of increasing bare soil reflectance.

As the bare soil component comprised such a large percentage of the individual pixels classified in these three landcover types throughout the watershed and there was not temporally coincident ground truth data, the whole pixel ISODATA procedure provides the most reliable, accurate results for landcover analysis. Subpixel analysis would have been an appropriate technical approach if temporally coincident ground truth data were available and if the image were selected in a more appropriate season. Subpixel analysis is able to detect materials that comprise as little as 20 percent of the pixel. Thus, utilizing the *Subpixel Classifier* process in areas with very low vegetative cover, less than 20 percent of a pixel, would have created many errors of commission.

The riparian zone classification offers a qualitative targeting method to spatially locate high risk landcover types within the riparian corridor. These highest risk landcover types would include bare soil/barren, planted/cultivated 1, and planted cultivated 2. When combined with estimates of nonpoint source loadings attributed to subwatersheds through SWAT modeling, it is anticipated that the combination will provide the watershed project coordinator with a mechanism to proactively identify and recruit landowners that are likely contributing to the overall degradation of water quality within the Fort Cobb Basin.

Appendix B - Water Quality Data

DATE	SITE NAME	FLOW CMS	TP mg/l	Nitrate mg/l	TKN + Nitrate mg/l	Soluble P mg/l
13-Aug-98	Lake Creek site #1	0.11	0.11	1.00	1.57	
13-Aug-98	Lake Creek site #4	0.07	0.15	2.04	2.70	
15-Sep-98	Lake Creek site #1	0.05	0.05	0.32	0.77	
15-Sep-98	Lake Creek site #4	0.03	0.10	2.00	2.66	
13-Oct-98	Lake Creek site #1	0.05	0.06	0.77	1.19	
13-Oct-98	Lake Creek site #4	0.05	0.15	2.33	2.76	
15-Dec-98	Lake Creek site #1	0.20	0.09	1.59	1.95	
15-Dec-98	Lake Creek site #4	0.13	0.14	2.24	2.81	
11-Jan-99	Lake Creek site #1	0.19	0.07	1.56	1.97	
11-Jan-99	Lake Creek site #4	0.11	0.14	2.18	2.72	
09-Feb-99	Lake Creek site #1	0.21	0.08	1.05	1.61	
09-Feb-99	Lake Creek site #4	0.11	0.22	3.30	4.41	
17-Mar-99	Lake Creek site #1		0.15	1.26	2.03	
17-Mar-99	Lake Creek site #4		0.23	1.88	2.66	
20-Apr-99	Lake Creek site #1		0.10	0.97	1.54	
20-Apr-99	Lake Creek site #4	0.09	0.12	2.12	2.61	
25-Apr-99	Lake Creek site #1		1.98	0.21	4.83	
20-May-99	Lake Creek site #1		0.16	1.23	1.55	
20-May-99	Lake Creek site #4		0.18	1.92	2.49	
13-Jun-99	Lake Creek site #1	0.15		1.14	1.68	
13-Jun-99	Lake Creek site #4	0.08		1.92	2.55	0.22
21-Jun-99	Lake Creek site #1	0.94	1.05	1.02	4.27	
20-Jul-99	Lake Creek site #1	0.10	0.12	0.45	0.88	
20-Jul-99	Lake Creek site #4	0.06	0.17	1.28	1.88	
17-Aug-99	Lake Creek site #1	0.06	0.08	0.25	0.77	
17-Aug-99	Lake Creek site #4	0.04	0.14	1.48	2.38	
31-Aug-99	Lake Creek site #1	0.05				
31-Aug-99	Lake Creek site #4	0.03				
20-Sep-99	Lake Creek site #1	0.05	0.07	1.03	1.60	
20-Sep-99	Lake Creek site #4	0.04	0.10	1.85	2.37	
19-Oct-99	Lake Creek site #1	0.06	0.07	0.59	46.19	
19-Oct-99	Lake Creek site #4	0.04	0.13	1.40	33.40	0.59
09-Nov-99	Lake Creek site #1		0.14	1.81	2.33	
09-Nov-99	Lake Creek site #4		0.15	2.27	2.83	
6/17/2000	22		0.31	0.98	2.57	0.25
6/17/2000	20		0.34	0.45	2.09	0.13
6/17/2000	24		0.38	0.70	2.25	0.20
6/17/2000	14		0.25	0.69	1.70	0.15
6/17/2000	13		0.23	0.90	2.05	0.19
6/17/2000	Add 2		0.23	0.01	0.89	0.07
6/17/2000	Add 1		0.10	0.39	0.90	0.20
6/17/2000	26		0.10	0.73	1.47	0.18
6/17/2000	15		0.26	0.48	1.55	0.15
7/13/2000	22		0.07	1.01	2.25	0.19
7/13/2000	20		0.11	0.94	2.37	0.21
7/13/2000	24		0.17	1.86	4.18	0.29
7/13/2000	14		0.29	1.17	3.43	0.35
7/13/2000	13		0.10	0.71	1.75	0.20
7/13/2000	Add 2		0.14	0.05	0.75	0.07
7/13/2000	Add 1		0.13	0.88	2.31	0.20
7/13/2000	26		0.10	0.37	1.33	0.09
7/13/2000	15		0.09	0.42	1.16	0.21

DATE	SITE NAME	FLOW CMS	TP mg/l	Nitrate mg/l	TKN + Nitrate mg/l	Soluble P mg/l
9/18/2000	22		0.06	0.79	1.98	0.18
9/18/2000	20		0.06	0.14	0.81	0.15
9/18/2000	24		0.09	1.83	4.07	0.21
9/18/2000	14		0.18	0.78	1.91	0.30
9/18/2000	13		0.04	0.24	0.82	0.17
9/18/2000	Add 2		0.00		0.00	0.00
9/18/2000	Add 1				0.00	0.00
9/18/2000	26		0.05	0.59	1.55	0.16
9/18/2000	15		0.07	0.01	0.41	0.19
11/29/2000	22		0.05	1.61	3.39	0.16
11/29/2000	20		0.07	1.27	2.80	0.16
11/29/2000	24		0.11	2.26	5.23	0.21
11/29/2000	14		0.16	1.49	3.11	0.31
11/29/2000	13		0.03	0.99	2.17	0.19
11/29/2000	Add 2		0.20	0.02	0.71	0.25
11/29/2000	Add 1		0.03	0.39	0.93	0.20
11/29/2000	26		0.04	0.62	1.49	0.15
11/29/2000	15		0.05	0.65	1.54	0.15
2/14/2001	22		0.06	1.31	2.99	0.16
2/14/2001	20		0.10	1.09	2.88	0.18
2/14/2001	24		0.07	1.96	4.37	0.19
2/14/2001	14		0.21	1.21	2.81	0.32
2/14/2001	13		0.05	1.01	2.41	0.16
2/14/2001	Add 2		0.04	0.01	0.43	0.13
2/14/2001	Add 1		0.04	0.31	0.83	0.13
2/14/2001	26		0.04	0.52	2.05	0.01
2/14/2001	15		0.07	0.73	1.90	0.18
4/23/2001	22	0.01	0.08	1.09	2.58	0.17
4/23/2001	20	0.22	0.14	1.12	3.25	0.19
4/23/2001	24	0.02	0.08	2.00	4.51	0.19
4/23/2001	14	0.02	0.15	0.95	2.20	0.27
4/23/2001	13	0.07	0.08	0.90	2.35	0.16
4/23/2001	Add 2		0.17	0.01	0.52	0.22
4/23/2001	Add 1	0.01	0.07	0.25	0.82	0.18
4/23/2001	26	0.10	0.08	0.91	2.24	0.17
4/23/2001	15	0.12	0.11	0.54	1.61	0.18
6/21/2001	22	0.01	0.08	1.01	2.26	0.18
6/21/2001	20	0.18	0.12	0.65	1.78	0.20
6/21/2001	24	0.02	0.13	1.99	4.27	0.28
6/21/2001	14	0.01	0.29	1.14	2.75	0.37
6/21/2001	13		0.10	0.69	1.72	0.20
6/21/2001	Add 2		0.25	0.01	1.01	0.15
6/21/2001	Add 1		0.15	0.10	0.95	0.20
6/21/2001	26	0.09	0.05	0.71	1.63	0.14
6/21/2001	15	0.07	0.09	0.41	1.13	0.20
9/16/2001	22	0.01	0.36	1.47	4.38	0.16
9/16/2001	20	0.05	0.06	0.10	0.78	0.13
9/16/2001	24	0.02	0.15	1.81	4.01	0.13
9/16/2001	14	0.01	0.20	0.85	1.97	0.25
9/16/2001	13	0.25	0.05	0.74	1.74	0.13
9/16/2001	Add 2		0.00		0.00	0.00
9/16/2001	Add 1		0.00		0.00	0.00
9/16/2001	26	0.07	0.04	0.63	1.53	0.12
9/16/2001	15	0.04	0.07	0.50	1.35	0.14

Appendix C - Quality Assurance Project Plan

Fort Cobb Basin - Modeling And Land Cover Classification Quality Assurance Project Plan

Submitted To The

Oklahoma Conservation Commission

For The

U.S. Environmental Protection Agency

Submitted by:

Dr. Daniel E. Storm, Professor
Michael J. White, Research Engineer,
Dr. Michael D. Smolen, Professor

Oklahoma State University
Department of
Biosystems and Agricultural Engineering
Stillwater, Oklahoma
May 7, 2002

Fort Cobb Basin - Modeling And Land Cover Classification
Quality Assurance Project Plan
Approval Page May 7, 2002

Plan Prepared by:

____
Daniel E. Storm, Project Director Date

Investigator Approval:

____
Michael D. Smolen, Professor, Biosystems and Agric. Engi. Date

Conservation Commission Approval:

____
Lawrence R. Edmison, Director, Water Quality Division Date

____
Dan Butler, Biologist, Water Quality Division Date

____
Shannon Phillips, QAPP Officer, Water Quality Division Date

Office of the Secretary of Environment Approval:

____
Jennifer Myers Wasinger, Environment Programs Manager Date

EPA Approval:

____
USEPA Region VI Office of Water Quality Date

Project Objectives and Responsibilities

Objectives and Purpose

The purpose of this study is to use the hydrologic model Soil and Water Assessment Tool (SWAT) to evaluate erosion and nutrient loading to the Ft. Cobb Reservoir. In addition, riparian corridors will be characterized. These analysis will be used to target and implement cost share and technical assistance programs. The following objectives are required to meet that goal:

- **Collect Ground Truth Data.**
  Ground truth data are required to perform accurate land cover classifications. Additional data may be collected to verify existing maps or GIS data.

- **Land cover classification.**
  Lansat TM (30m) resolution imagery will be classified into a land cover map. In this process, pixels are selected that represent patterns or land-cover features that can be recognized or identified with help from other sources, such as ground truth data, aerial sources, or maps.

- **Riparian corridor characterization.**
  This process will utilize IMAGINE Subpixel Classifier software that has the ability to detect and report whole and subpixel occurrences of a specific material in multi-spectral imagery. IMAGINE Subpixel Classifier classifies all pixels that contain the material into classes based on how much of the material they contain.

- **Collect and process model input data.**
  Geographic Information System (GIS) data for topography, soils, land cover, and streams are required by the SWAT model. An ArcView GIS interface is available to summarize the GIS data and convert it to a form usable by the model.

- **Model Calibration.**
  Calibration is the process by which a model is adjusted to more closely match observed data. Calibration greatly improves the accuracy of a model. The SWAT model will be calibrated on observed streamflow from all suitable US Geologic Survey (USGS) gages.

- **Targeting High Erosion Areas.**
  Based on SWAT predicted erosion rates, problematic combinations of soils, land cover, and slope will be used to target critical areas. The final product will be a basin map showing highest erosion areas shaded by severity.

Project Participants

Biosystems and Agricultural Engineering Department, Oklahoma State University
Dr. Daniel E. Storm, Professor
Mr. Michael J. White, Research Engineer
Dr. Michael D. Smolen, Professor

Responsibilities:
- Collect and process model input data.
- Model Calibration.
- Targeting High Erosion Areas.

Applied Analysis Incorporated
Dr. Scott Stoodley, Director of Environmental Water Quality Programs

Responsibilities:
- Land cover classification.
- Riparian corridor characterization.

Oklahoma Conservation Commission
Dan Butler, Aquatic Biologist

Responsibilities:
- Collect Ground Truth Data.

Data Sources and Selection

Basin scale hydrologic modeling requires a vast amount of data. The modeling report will contain all data sources and references. These data come from a variety of sources:

Data Name	Data class	Data Type	Data Source
10 m DEM	GIS	Elevation	US Geological Survey
MIADS	GIS	Soils	Oklahoma Natural Resource Conservation Commission
Landsat imagery	Image	Multi-spectral	Satellite Imaging
Ground truth	Tabular		Oklahoma Conservation Commission Personnel
STATSGO database	Tabular	Soils	Soil and Water Assessment Tool
NEXRAD precipitation	Tabular	Weather	Arkansas-Red Basin Forecast Center
NOAA Cooperative Observer Network	Tabular	Weather	National Oceanic & Atmospheric Administration
Soil test phosphorous	Tabular	Soil test Phosphorus	Oklahoma State University Soil, Water & Forage Analytical Laboratory
Management operations	Tabular	Management	Cooperative Extension Publications
Stream gage	Tabular	Streamflow	US Geological Survey

Often there are several data sets available from which to choose for a particular modeling task. These data are evaluated based on the following criteria:

1. **GIS data detail.**
   GIS data come in a variety detail levels, the level of detail may be expressed as a resolution or map scale. White (2001) found that the detail of input GIS data has a significant impact on SWAT model output.

2. **Age of data set.**
   Some data used are more time sensitive than others. For example, land cover may change dramatically over the span of a decade, where as soils typically change only over geologic time.

3. **Accuracy.**
   Accuracy information is seldom available. In these cases the accuracy is assessed by professional judgement.

4. **Temporal continuity.**
   Temporal continuity is of great importance when selecting weather, streamflow, or water quality data. Weather and streamflow should ideally be continuous on a daily basis, although it is possible to estimate missing days based on other data. These data are seldom continuous for long period of time.

5. **Spatial Consistency.**
   Spatial consistency is often sacrificed to use the most current data available. Most data sets cover only a limited area such as a state or county. A basin is typically not limited to those same boundaries, and often cross both state and county lines. This leads to the use of multiple GIS data sets to define a single model input layer and may create a lack of consistency across the basin.

Quality and Limitations of SWAT Model Data

It is not currently possible to comprehensively quantify the error in SWAT model predictions, thus there are no quantitative data quality requirements. It is, however, possible to list limitations. Model limitations may be the result of data used in the model, inadequacies in the model, or using the model to simulate situations for which it was not designed. Hydrologic models will always have limitations, because the science behind the model is neither perfect nor complete. A model by definition is a simplification of the real world. The following is a list of notable SWAT model limitations:

- **Weather**
  Weather is the driving force for any hydrologic model. Data collected at a few points is applied to an area of thousands of square miles. Rainfall can be quite variable, especially in the spring when convective thunderstorms produce precipitation with a high degree of spatial variability. It may rain heavily at a weather station, but may be dry a short distance away. On an average annual or average monthly basis, these errors have may cancel. This limitation among others, caution us against using model output on a daily or monthly basis.

- **Radical Parameter Changes**
  Scenarios involving radical changes to the basin result in greater uncertainty. The SWAT model is calibrated using estimates of what is presently occurring in the basin. Large departures from calibration conditions raise the level of uncertainty in model predictions.

- **Small Land Covers**
  Land uses that cover very small areas are not represented in the SWAT model. Land uses that occupy limited areas such as unpaved roads, bare areas, construction sites, and some row crops may not be simulated. In addition, most of these features may not be depicted in the available land cover. Some of these small areas may contribute many times more sediment on a per unit area basis than rangeland. Although significant, they may not be able to be simulated with the currently available data.

- **Hydrologic Response Unit (HRU) Characteristics**
  Each HRU in a particular subbasin is assumed to have the same characteristics by the SWAT model. For instance, the same slope is used for all rangeland and agricultural HRUs in a single subbasin. Agricultural land is generally located in valleys or other flat areas. Rangeland generally occupies land that is unsuitable for row crop production.

- **Management Uncertainty**
  There is a great deal of uncertainty associated with management. In reality, management varies significantly from field to field. It is not possible to easily determine what is happening where, or to simulate all these activities in the

model. Therefore, categories are created to cover reasonable managements choices only.

- **Unidentified Point Sources**
  There are many point sources in the basin; these could be significant. Potential point sources include household septic systems, CAFOs, and municipalities.

- **Instream Process**
  SWAT models in-stream processes based, in large part, on unvalidated assumptions of channel and stream-bank properties. Therefore these process will be turned off and not utilized.

Data Reporting, Reduction, and Validation

Reporting.

A final report will be prepared for this project. The report will include sufficient information to meet the project objectives.

Data Reduction.

Models, such as SWAT, may generate a vast amount of data that must be summarized. A great deal of these data are of no interest to the user and are discarded. These data are so varied in type, format, and resolution, that summarizing techniques are selected on a case by case basis using best professional judgement.

Validation

Validation is the process of verifying the ability of a calibrated model to make predictions outside the calibration period. A portion of the available stream flow record is withheld during calibration and later used to validate the model. The SWAT model may be validated depending on the amount of available stream flow data. If little observed stream flow are available, no model validation will be performed.